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A SIMULATION AND TRAINING TECHNOLOGY SURVEY

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This report documents an effort to identify training technology priorities to guide R&D programs at the Naval Air Warfare Center Training Systems Division (NAWCTSD; formerly the Naval Training Systems Center, NTSC), with potential generalizability across the military. A Simulation and Training Technology Survey (STTS) was developed and administered to training experts in government and private industry. Results from the survey were examined for R&D implications.

The survey identifies and defines 91 training technologies that are suitable topics for R&D programs. The major finding from the survey is that training experts consider most, if not all, of these technologies important topics for future R&D. A review of related efforts to define training technology priorities for R&D showed high similarity with the current results. Relative priorities for specific technologies are identified, with special consideration given to validity issues.

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EXECUTIVE SUMMARY

PROBLEM

The Navy needs to reduce training costs while at the same time train faster, to a higher level, and save lives and equipment. These improvements require that we prioritize training technologies for Research and Development (R&D), and select the technologies with the greatest potential for return on the R&D investments.

OBJECTIVE

This report documents an effort to identify training technology priorities to guide R&D programs at the Naval Air Warfare Center Training Systems Division (NAWCTSD; formerly the Naval Training Systems Center; NAVTRASYSCEN), with potential generalizability across the military.

METHOD

A Simulation and Training Technology Survey (STTS) was developed and administered to training experts in government and private industry. Results from the survey were examined for R&D implications.

RESULTS AND CONCLUSIONS

This STTS identifies and defines 91 training technologies that are suitable topics for R&D programs. The major finding from the survey is that training experts consider most, if not all, of these technologies important topics for future R&D. A review of related efforts to define training technology priorities for R&D showed a high degree of similarity with the current results.

Relative priorities for specific technologies are identified, with special consideration given to validity issues.

RECOMMENDATIONS

o Consider all technology areas identified in the STTS for development and implementation.

o Prioritize selected topics for R&D based on findings presented in this report together with the benefits, costs, risks, and applicability of particular technical developments. Criteria such as described in the NAVPERSDEVCEN-NAVTRASYSCEN Plan (Appendix B) should help guide this process.

o Improve Navy research and test facilities to better evaluate promising technologies.

o Improve evaluations of fielded training systems to assure their proper use and cost effectiveness.

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INTRODUCTION

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"People and associated training requirements cost 60% of weapon systems life cycle costs" (Investment strategy, 1992, p.7). With ever shrinking resources, the Navy needs to reduce these costs while at the same time train faster, to a higher level, and save lives and equipment. These improvements require better and less expensive training technology. In turn, this requires that we prioritize technologies for Research and Development (R&D), and select the technologies with the greatest potential for return on the R&D investments.

OBJECTIVE

Technologies are prioritized, implicitly or explicitly, each time a training R&D program is initiated. Occasionally, efforts are made to define shortcomings in training technologies more globally, to guide R&D across a range of programs. This report documents an effort to identify R&D priorities to guide programs at the NAWCTSD (formerly NAVTRASYSCEN), with potential generalizability across the military. This effort took the form of a Simulation and Training Technology Survey (STTS).

BACKGROUND

Additional surveys and analyses that can help identify training technologies for future R&D efforts include: (a) Training Systems Technology Assessment Plan of Action and Milestones (1991); (b) NAVTRASYSCEN Inputs to Navy Training Appraisal (1989); (c) 1991 Navy Training Appraisal Space and Electronic Warfare Issue Development (1991); (d) Desert Shield and Desert Storm Implications for Future U.S. Force Requirements (Collins, 1991); (e) Navy Training Plans; (f) Report of Industry Task Force Navy Training-2000 (1990); (g) Investment Strategy for Training Systems Technology Area Exploratory Development (NAVPERSDEVCEN-NAVTRASYSCEN Plan, 1992).

The latter two reports, most closely related to the current effort, are discussed briefly in the following.

Training-2000

In February 1989, Rear Admiral Cressy, Director of Aviation Manpower and Training with the Chief of Naval Training, initiated an effort to identify training technologies that can have application to naval training, particularly aviation, in the year 2000 and beyond. Toward this end, a committee of 18 individuals from government and industry identified 18 technologies that are ready for exploitation through R&D (Appendix A). Fifteen of these 18 technologies also are identified (conceptually) as important R&D topics in the STTS (presented later in this report). The three exceptions are: Fiber Optics, Telecommunication Satellites, and Training Effectiveness Assessment Tools.

The committee also recommended funding for research on six research issues that encompass nine training technologies (Appendix A). Again, there is considerable overlap between this list and technologies identified for R&D by the STTS. Except for Mission Planning and Mission Rehearsal, all technology areas recommended for funding in the Training-2000 report also are recommended for R&D in the STTS. The STTS includes Mission Planning and Mission Rehearsal as Military Training Requirements, i.e., operational objectives toward which the technologies are directed.

The close similarity in the technologies identified in these two efforts shows high consensus in the military training community concerning the most critical technologies to advance through R&D.

NAVPERSDEVCEN-NAVTRASYSCEN PLAN

The NAVPERSDEVCEN-NAVTRASYSCEN Plan (1992), developed by the Naval Personnel Research and Development Center (NAVPERSDEVCEN) with contributions from the NAVTRASYSCEN, gives plans and rationale for Exploratory Development on military training issues. The rationale consists of 13 trends in Navy training (e.g., fewer people) and 22 requirements for dealing with the trends (e.g., widely available cross training). The plan recommends R&D on 17 technologies (e.g., networks/distributed training) to satisfy the requirements.

All 17 technologies also are recommended for R&D by the STTS effort. This further supports the priority of the technologies identified.

In addition to the above, the Plan also presents a more extensive list of technologies with associated definitions. This list contains 16 technologies categorized as delivery technologies, 20 as instructional processes and methods, and 32 as supporting technologies. Together, the two lists show specific technologies that support more general technologies and how the technologies support Navy requirements. This framework is similar to the structure of the STTS. Major conclusions from the Plan are shown in Appendix B.

The technologies identified in the Plan are important areas for R&D and operational implementation.

METHOD

SURVEY DEVELOPMENT

The STTS (Appendix C) was developed by research personnel at the NAVTRASYSCEN with significant contributions from private industry. Technologies were initially defined in brief papers, written in support of the survey by technical experts at the NAVTRASYSCEN. The papers covered the major R&D thrust areas currently underway or in plans at the NAVTRASYSCEN. Technologies identified in the papers became the content of the survey. The papers were appended to the survey to serve as background information for completing the survey. Draft copies of the survey were distributed to individuals at the NAVTRASYSCEN and in private industry for review and critique. The survey was modified based on comments from the reviewers.

The STTS has a hierarchical structure to relate technologies at different levels of specificity and to show how each technology supports military objectives. At the top of the hierarchy, 11 Military Training Requirements illustrate broad operational objectives toward which R&D programs must be directed. The second level contains nine Delivery Methods/Strategies, which are approaches for administering instruction to satisfy the military requirements. At the third level, 17 Training Technologies define general capabilities that allow the Delivery Methods/Strategies to be implemented. Sixty five Enabling Technologies are included at the fourth and final level, to identify specific capabilities that support the development of Training Technologies. The Enabling Technologies have development milestones.

For example, one of the 11 Military Training Requirements listed in the survey is, Save training resources. Embedded Training is one of nine Delivery Methods/Strategies proposed to satisfy this and other military training requirements. Training and Organizational Management is identified as one of three Training Technology areas that require development in order to implement Embedded Training. Training and Organizational Management is proposed to depend on Enhanced lesson and scenario authoring (along with two other Enabling Technologies). Finally, the survey predicts that a prototype tool for automated scenario authoring will be available by 1995, and the tool will be ready for general use by the year 2000. This indicates that, given the current pace of R&D, lesson and scenario authoring technologies should be ready to support Embedded Training by 2000. It also predicts that Embedded Training will more effectively satisfy operational requirements when this and the other supporting technologies identified in the STTS are developed.

The respondents' main objective was to identify the importance of advancing technologies identified at each level in the hierarchy, relative to competing methods and technologies of which they were aware. This was accomplished by rating each item on a five-point scale, ranging from (1) = Very Critical to (5) = Minimally Critical.

The respondents also rated their level of competence for each criticality rating given. Competence ratings were made on a five-point scale, where (1) = Very Knowledgeable and (5) = Limited Knowledge. The survey requested information on the rater's background/experience, and invited the respondent to comment on any aspect of the survey and to add and rate new requirements, methods, and technologies, as appropriate.

SURVEY IMPLEMENTATION

In Spring 1992, the final version of the survey was delivered to 18 individuals from the NAVTRASYSCEN and private industry who agreed to complete the survey. The respondents were solicited from among those who contributed to the development of the survey and from the membership of the National Security Industry Association R&D Subcommittee.

Thirteen of the 18 people responding to the solicitation indicated an educational background in engineering/physical science; three identified behavioral science as their major educational qualification; one was educated at the U.S. Military Academy; and educational information was missing from one respondent. Their level of experience in training areas ranged between six and 35 years, with a mean of over 20 years.

Individuals and organizations contributing directly to the development of the survey and providing responses to the survey are listed in Appendix D.

RESULTS AND DISCUSSION

All survey rating data are reported as means and standard deviations. Inferential tests of significance were not made because the sample of raters was considered too small in number and insufficiently diverse in background to adequately assess the diversity of technologies included on the survey, and, therefore, to generalize the findings to a larger community of training experts.

In particular, because only three of the respondents had significant experience in the behavioral sciences, and one of these individuals completed only a portion of the survey, the ratings corresponding to behavioral elements of the survey probably are least representative of general expert opinion. As a group, the respondents also rated themselves as less competent on the behaviorally oriented items, thus reinforcing the suspicion that the judgements given to behavioral elements are less representative of general expert opinion.

Marketing strategies could place additional influences on survey responses from individuals in private industry. Technologies with high economic value to private industry could be attributed inappropriately high levels of criticality.

Caveats such as these should influence interpretations of the findings, but should not negate the major contributions. The current effort, building upon previous efforts, has helped define, reinforce and extend the rationale, operations, and plans of the major training and simulation industry. It involved much effort from many experts, and makes significant contributions toward improving and updating commonly shared conceptions of advanced and advancing technologies. Other such efforts must build on the current effort to help assure efficient progress, through coordinated conceptualizations, toward common training goals.

DELIVERY METHODS

The mean Criticality ratings associated with the Delivery Methods ranged between 1.8 and 3.2 (Table 1). Seven of the nine Methods were rated at least "Moderately Critical" (3.0). The overall mean and standard deviation, across all Methods, were 2.6 and 1.0, respectively. This indicates that the respondents differed among themselves about the criticality of specific Delivery Methods, but overall considered the Methods to be important subjects for R&D.

A 2.6 overall Criticality rating is considered especially favorable because the criterion for the highest rating was extremely stringent. The highest (Very Critical) rating means that

Table 1

DELIVERY METHODS:
CRITICALITY & COMPETENCE RATINGS
(N=18)

DELIVERY METHOD	CRITICALITY			COMPETENCE		
	RANK	RATING	STD DEV	RANK	RATING	STD DEV
Team Training	1.5	1.8	.8	2.5	2.7	.8
Deployed Training	1.5	1.8	.8	1.0	2.5	.7
Multi Player Exercises	3.0	2.3	1.2	7.0	2.9	1.0
Virtual Reality	4.0	2.5	.8	5.0	2.8	1.1
Emulation	5.5	2.8	.8	5.0	2.8	1.1
Embedded Training	5.5	2.8	.9	8.0	3.0	.9
Interactive Courseware	7.0	3.0	1.2	5.0	2.8	1.1
Wargaming on Ranges with Operational Equip	8.5	3.2	1.3	9.0	3.3	1.4
Low Cost PC Applications	8.5	3.2	1.3	2.5	2.7	1.1
OVERALL MEANS AND STD DEV		2.6	1.0		2.8	1.0

Key: 1 = Very Critical/Very Knowledgeable
3 = Moderately Critical/Knowledgeable
5 = Minimally Critical/Limited Knowledge

"Progress is more important than for any other capability." This high criterion encourages discrimination among the training areas. But it also severely limits the number of areas that can qualify for a "Very Critical" rating, which would decrease the average ratings on all survey items.

Team Training and Deployed Training tied for the highest Criticality rating among the Delivery Methods. Multi-Player Exercises ranked third, and Virtual Reality ranked fourth. The high ratings given to these four areas reflects their recent emphasis in the training community.

The top ratings given to the two Delivery Methods used to teach people to work as collective units -- Team Training and Multi-player Exercises -- shows strong interest in "collective training" issues in general. Team Training, the highest rated Delivery Method, focuses on instructional elements of collective training, such as exercise development, performance measurement, and debriefing techniques. Multi-Player Exercises, rated in third place, deals mainly with engineering aspects of collective training, in the form of networking.

The remaining five Delivery Methods -- Emulation, Embedded Training, Interactive Courseware, Wargaming on Ranges, and Low Cost PC Applications -- were rated lower in criticality, in the order given.

As a group, the respondents considered themselves to be at least Moderately Competent with the Delivery Methods, except for Wargaming on Ranges with Operational Equipment (which received a 3.3 rating). The overall mean for Competence was 2.8, with a standard deviation of 1.0.

There appears to be no significant relationship between the overall Competence ratings and Criticality ratings. This adds validity to the results: the respondents as a group did not rate a Delivery Method as more important simply because they were more familiar with it.

A further observation is that the respondents' Criticality ratings were less variable for Delivery Methods rated higher in Criticality. This is shown in Table 1, where all but one of the six Methods rated highest in Criticality have lower standard deviations (.8 and.9) than the three Methods rated lowest in Criticality (1.2 and 1.3). Apparently, the Criticality of the highest rated items was sufficiently evident to create high agreement among the raters.

A separate analysis of responses for just the three behavioral respondents revealed a somewhat different ordering of Criticality and Competence, as shown in Table 2. Because ratings for engineering and behavioral items differed dramatically depending on the background of the rater and representation of behavioral raters was so low, it seems appropriate to consider the behavioral ratings separately.

Table 2 shows that, for the behavioral respondents, Team training ranked highest and Wargaming on Ranges ranked among the lowest. These priorities are nearly identical to those found for the total group of respondents. But, Interactive Courseware and Low Cost PC Applications ranked high (second and third) for the behavioral respondents and low (last and second last) for the total

Table 2

DELIVERY METHODS:
BEHAVIORAL CRITICALITY & COMPETENCE RATINGS
(N=3)

DELIVERY METHOD	CRITICALITY			COMPETENCE		
	RANK	RATING	RANGE	RANK	RATING	RANGE
Team Training	1.0	1.0	1	2.5	1.5	1-2
Low Cost PC Applications	2.5	1.5	1-2	2.5	1.5	1-2
Interactive Courseware	2.5	1.5	1-2	2.5	1.5	1-2
Embedded Training	5.5	2.0	2	2.5	1.5	1-2
Virtual Reality	5.5	2.0	2	6.0	2.5	2-3
Deployed Training	5.5	2.0	2	7.5	3.0	3
Emulation	5.5	2.0	1-3	5.0	2.0	1-3
Wargaming on Ranges with Operational Equip	8.5	3.0	3	7.5	3.0	3
Multi Player Exercises	8.5	3.0	2-4	9.0	3.5	3-4
OVERALL MEANS & RANGES		2.0	1-4		2.2	1-4

Key: 1 = Very Critical/Very Knowledgeable
3 = Moderately Critical/Knowledgeable
5 = Minimally Critical/Limited Knowledge

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group. Also, Deployed Training tied for first rank in the overall group ratings, but was ranked lower by behavioral raters.

As expected, Competence ratings for the behavioral respondents also showed large differences compared with engineering respondents, mainly with higher Competence for Interactive Courseware and lower Competence for Deployed Training.

TRAINING TECHNOLOGIES

Table 3 shows that 16 of the 17 Training Technologies (94%) have mean Criticality ratings ranging between 1.7 and 2.9, indicating Moderately Critical or higher. The one exception, Training and Organizational Management, has a mean Criticality rating of 3.5. The overall mean and standard deviation across all Training Technologies were 2.6 and 1.0, respectively. These overall measures are identical with those obtained for Delivery Methods, and the implications are the same: respondents differed with each other regarding the criticality of specific Technologies, but they generally agreed that the Technologies are important areas for R&D.

Visual/Sensor Simulation -- which applies to a variety of Delivery Methods -- received the highest Criticality rating among the Training Technologies. Carrier Based Weapons System Trainer received the second highest rating. Four tied for third highest rating: the Visual Displays component of Virtual Reality, Networking, Team Performance Measurement Systems, and Team Training Systems. The high ratings for the two visual technologies included on the survey reflects a long-term community emphasis on visual issues.

Criticality ratings for the remaining 11 Training Technologies gradually declined, with only small (.2 or less) differences among successively ranked items. The one exception is Training and Organizational Management -- the lowest rated item, which was rated .6 lower in Criticality than the next to lowest rated item.

Similar to Delivery Methods, the Criticality ratings were less variable for Technologies rated more Critical. This is shown in Table 3, where all but one (Networking) of the six Training Technologies ranked highest in Criticality have relatively low standard deviations (between .6 and .9), whereas all but one (Tactile Displays) of the eleven Training Technologies rated lower in Criticality have higher standard deviations (between 1.0 and 1.3). Again, the Criticality of the highest rated items was sufficiently evident to produce high agreement among the raters.

The respondents considered themselves to be moderately knowledgeable on the Training Technologies, with Expert Systems, Carrier-Based Weapon System Trainer and Visual Displays receiving the highest Competency ratings (2.3, 2.5, and 2.5, respectively). They rated themselves least competent with Training and Organizational Management, Eye Movement Transducers and Team Training Needs Analysis System (3.8, 3.6, and 3.5, respectively).

Table 3

TRAINING TECHNOLOGIES:
CRITICALITY AND COMPETENCE RATINGS
(N=18)

TRAINING TECHNOLOGY	CRITICALITY			COMPETENCE		
	RANK	RATING	STD DEV	RANK	RATING	STD DEV
Visual/Sensor Sim	1.0	1.7	.6	4.5	2.6	1.3
Carrier-Based WST	2.0	2.0	.9	2.5	2.5	1.0
Team Training System	4.5	2.1	.9	6.5	2.7	1.0
Team Performance Measurement System	4.5	2.1	.8	11.5	3.1	.7
Networking	4.5	2.1	1.3	6.5	2.7	1.2
Visual Displays	4.5	2.1	.9	2.5	2.5	1.1
Threat Modeling & Common Data Bases	7.0	2.2	1.1	4.5	2.6	1.2
Automated Scenario Gen & Control	8.0	2.3	1.2	8.5	2.8	1.2
Engr Technologies	9.0	2.5	1.2	8.5	2.8	1.0
Expert Systems	10.0	2.5	1.0	1.0	2.3	1.0
Team Trng Needs Analysis System	12.0	2.7	1.0	15.0	3.5	.8
Instr/Observer Training System	12.0	2.7	1.0	11.5	3.1	1.0
Tactile Displays	12.0	2.7	.8	13.5	3.2	1.0
Audio Displays	14.5	2.8	1.0	10.0	2.9	.9
Auto Instr Support	14.5	2.8	1.2	13.5	3.2	.9
Eye Movement Transducers	16.0	2.9	1.0	16.0	3.6	1.3
Tng & Organ Mgmt	17.0	3.5	1.0	17.0	3.8	.7
OVERALL MEANS AND STD DEV		2.6	1.0		2.9	1.0

Key: 1 = Very Critical/Very Knowledgeable
3 = Moderately Critical/Knowledgeable
5 = Minimally Critical/Limited Knowledge

The overall mean Competency rating and standard deviation were 2.9 and 1.0, respectively, nearly identical to those discussed earlier for Delivery Methods.

In contrast with the Delivery Methods results, the respondents rated Training Technologies with which they were more competent as also more Critical. Table 3 shows that except for Team Performance Measurement System, all of the Technologies ranked in the top ten in Criticality are also ranked in the top ten in Competence. This tendency to rate more familiar topics as more critical is quite evident for the behaviorally oriented items. The five Technologies with clear behavioral orientations -- Team Performance Measurement System, Team Training Needs Analysis System, Instructor/Observer Training System, Training and Organizational Management, and Automated Instructor Support -- have lower ratings in both Criticality and Competence compared with the remaining 12 technologies, that have stronger engineering orientations. The mean Criticality ratings for the five "behavioral" and 12 "engineering" items are 2.7 and 2.3, respectively. The mean Competence ratings for the for the five behavioral and 12 engineering items are 3.3 and 2.7, respectively.

Greater familiarity with a technology may create a perception of greater criticality. Alternately, a perception of greater criticality may stimulate efforts to become more familiar with an area. It seems that the former was a strong factor, since the respondents' predominantly engineering background would require familiarity with the engineering technologies, which allows relatively little time to develop competence with behavioral technologies, even those that may be considered critical. In either case, it would be more difficult to accurately assess the importance of a technology with which one has little familiarity. So, criticality ratings should be viewed with increased caution for technologies with low competence ratings; these being primarily the technologies with strong behavioral orientations.

Table 4 shows that the three highest Criticality ratings and one of the second highest ratings assigned by the three behavioral respondents all are associated with Team Training. This is consistent with the high ratings given by the total group of respondents to Team Training as a Delivery Method, but contrasts with the much lower ratings given to these four Training Technologies by the total group. (In the total group analysis, two of the four Training Technologies tied with four others for third highest rating and the other two tied for 12th rank.) This shows agreement between practitioners in the engineering and behavioral disciplines about a training capability required by the military, but reveals fundamental differences concerning technologies required to achieve the capabilities.

Table 4

TRAINING TECHNOLOGIES:
BEHAVIORAL CRITICALITY AND COMPETENCE RATINGS
(N=3)

TRAINING TECHNOLOGY	CRITICALITY			COMPETENCE		
	RANK	RAT ING	RANGE	RANK	RAT ING	RANGE
Team Trng System	2.0	1.5	1-2	3.0	2.0	2
Team Perf Meas Sys	2.0	1.5	1-2	3.0	2.0	2
Team Trng Needs Analysis System	2.0	1.5	1-2	3.0	2.0	2
Instr/Observer Training System	5.0	2.0	2	3.0	2.0	2
Expert Systems	5.0	2.0	1-3	3.0	2.0	1-3
Automtd Scen-ario Gen & Cntl	5.0	2.0	1-3	16.0	3.3	1-3
Vis/Sens Sim	8.0	2.5	2-3	11.5	3.0	2-4
Tactile Displs	8.0	2.5	2-3	6.5	2.5	2-3
CV-Based WST	8.0	2.5	2-3	11.5	3.0	3
Networking	13.0	3.0	2-4	6.5	2.5	3-4
Threat Modlg & Com Data Bases	13.0	3.0	3	11.5	3.0	3
Visual Displays	13.0	3.0	3	11.5	3.0	3
Engr Tech	13.0	3.0	3	11.5	3.0	3.0
Audio Displs	13.0	3.0	3.0	11.5	3.0	3
Auto Instr Sup	13.0	3.0	2-4	11.5	3.0	2-4
Eye Movement Transducers	13.0	3.0	3	11.5	3.0	3
Tng & Organ Mgmt	17.0	3.5	3-4	17.0	3.5	3-4
OVERALL MEANS & RANGES		2.5	1-4		2.7	1-4

Key: 1 = Very Critical/Very Knowledgeable
3 = Moderately Critical/Knowledgeable
5 = Minimally Critical/Limited Knowledge

This discrepancy in ratings between engineering and behavioral specialists also was found for Automated Scenario Generation and Control and Expert Systems. These items were in the highest two ranks for the behavioral raters, but ranked eighth and tenth, respectively, for the total group.

Behavioral respondents were in exact agreement with the total group concerning the four Training Technologies ranked lowest in Criticality: Audio Displays, Automated Instructional Support, Eye Movement Transducers, and Training and Organizational Management. It may be somewhat surprising that Automated Instructional Support and Training and Organizational Management, major behavioral areas, ranked so low with the behavioral raters. But this can be explained by the fact that only two behavioral responses were available for each of the two items.

ENABLING TECHNOLOGIES

Table 5 shows mean ratings given to Enabling Technologies, grouped according to the Training Technologies and Delivery Methods they support. As was found for Delivery Methods and Training Technologies, most -- 57 of 65 (88%) -- of the Enabling Technologies were rated Moderately Critical or higher. The range of the Criticality ratings -- 1.5 through 3.9 -- is considerably larger than obtained for Delivery Methods and Training Technologies, presented in the earlier analyses. This is expected, because the larger number of Enabling Technologies increases the chances for variation.

The overall mean Criticality rating for Enabling Technologies was 2.5; the overall standard deviation was 1.0. Again, these results are nearly identical to results discussed earlier for the two higher-order categories. The implications are also similar to the earlier analyses: these results show that the respondents consider the Enabling Technologies to be important areas for R&D.

Criticality ratings given to the 22 Enabling Technologies associated with the four highest rated Delivery Methods -- Team Training, Deployed Training, Multi-Player Exercises, and Virtual Reality, with only two exceptions, have Moderately Critical or higher ratings. The two exceptions are Network Security and Head-mounted Stereo (rated 3.1 and 3.2, respectively.) This indicates that, in the respondents' judgements, the Enabling Technologies were appropriate issues for investigation to advance the most important Delivery Methods.

TABLE 5

ENABLING TECHNOLOGIES: CRITICALITY AND COMPETENCE RATINGS
(N=18)

DELIVERY METHOD*	TRAINING TECH.	ENABLING TECH.	CRITICALITY			COMPETENCE		
			RANK	RATING	STD DEV	RANK	RATING	STD DEV
TEAM TRAINING	Team Training System	-Exercise devel	32.3	2.5	.7	31	3.0	.9
		-Team trng strategies	32.5	2.5	.6	35	3.1	.7
		-Computer technology	32.5	2.5	1.1	18	2.7	1.0
	Team Perf Meas Sys	-Teamwork skills meas	20	2.3	.8	35	3.1	.7
		-Trng eval meas	20	2.3	.9	38.5	3.2	.8
		-Diagnos mechs	38	2.6	.8	45	3.3	.7
	Team Trng Needs Anal Sys	-Needs anal survey	42	2.7	1.0	45	3.3	.8
		-Mult anal of perf	50	2.9	.8	55	3.5	.9
	Instr/ Observer Trng Sys	-Task/team related guided fdbk	38	2.6	.9	45	3.3	.7
		-Trng delivery	50	2.9	.8	27.5	2.9	.8
		-Pre-trng capability diagnosis	56	3.0	.6	55	3.5	.7

* Enabling Technologies were not identified for Interactive Courseware, Wargaming on Ranges With Operational Equipment, Emulation, and Low Cost Operations. These Delivery Methods were omitted from this table.

Key: 1 = Very Critical/Very Knowledgeable
3 = Moderately Critical/Knowledgeable
5 = Minimally Critical/Limited Knowledge

TABLE 5 (Cont.)

DELIVERY METHOD	TRAINING TECHNOLOGY	ENABLING TECHNOLOGY	CRITICALITY			COMPETENCE		
			RANK	RATING	STD DEV	RANK	RATING	STD DEV
DEPLOYED TRAINING	Carrier-Based Weapons System Trainer	-Reconfig low maint cockpit	12.5	2.1	1.2	5.5	2.3	1.2
		-Photo-based image generater	20	2.3	.9	9.5	2.5	1.0
		-Mini displays	38	2.6	1.2	7.0	2.4	.9
MULTI-PLAYER EXERCS	Networking	-Data base math model develop	12.5	2.1	1.2	14.0	2.6	1.2
		-Data transfer	12.5	2.1	1.2	22.0	2.8	1.3
		-Environ params modeling	45.5	2.8	1.1	27.5	2.9	1.2
		-Network security	60	3.1	1.0	55.0	3.5	1.0
VIRTUAL REALITY	Visual Displays	-Head-mounted visual displays	2.5	2.1	.7	22.0	2.8	1.1
	Tactile Displays	-Force simul	42	2.7	1.0	50.0	3.4	1.0
	Audio Displays	-Head-mounted stereo	62	3.2	.9	38.5	3.2	1.1
	Eye Mvmnt Transducer	-Eye track	45.5	2.8	1.1	55.0	3.5	1.3

Key: 1 = Very Critical/Very Knowledgeable
3 = Moderately Critical/Knowledgeable
5 = Minimally Critical/Limited Knowledge

TABLE 5 (Cont.)

DELIVERY METHOD	TRAINING TECHNOLOGY	ENABLING TECHNOLOGY	CRITICALITY			COMPETENCE		
			RANK	RATING	STD DEV	RANK	RATING	STD DEV
EMBEDDED TRAINING	Engineering Technologies	-Sys safety	12.5	2.1	1.3	55.0	3.5	1.0
		-Sys stimul	26.5	2.4	1.2	35.0	3.1	.9
		-Sys fail safe	26.5	2.4	1.4	55.0	3.5	.9
		-Sys mode conversion	45.5	2.8	1.2	38.5	3.2	.9
	Automated Instructional Support	-Intel agents	26.5	2.4	1.1	18.0	2.7	1.1
		-Auto perform meas & feedbk	38.0	2.6	1.4	45.0	3.3	1.1
		-Missing team memb	45.5	2.8	1.1	45.0	3.3	.8
		-Auto adaptive instruct.	56.5	3.0	1.4	55.0	3.5	1.0
	Training and Organizational Management	-Lesson & scenario authoring	60.0	3.1	1.1	62.0	3.7	.8
		-Auto record management	64.0	3.6	1.1	55.0	3.5	1.0
		-Coord & standardization	65.0	3.9	1.0	64.0	3.8	.9

Key: 1 = Very Critical/Very Knowledgeable
3 = Moderately Critical/Knowledgeable
5 = Minimally Critical/Limited Knowledge

TABLE 5 (Cont.)

DELIVERY METHOD	TRAINING TECH	ENABLING TECH	CRITICALITY RANK	CRITICALITY RATING	CRITICALITY STD DEV	COMPETENCE RANK	COMPETENCE RATING	COMPETENCE STD DEV
BROAD DEVEL STRATGS - TECHS TARGET MULTIPL DELIV METHODS/ STRATGS & TRNG TECH	Threat Modeling and Common Data Bases	-Inter- operblty	1.5	1.5	.7	5.5	2.3	.9
		/correl				14.0	2.6	.9
		-Data	16.0	2.2	.7			
		sources				9.5	2.5	.8
		-Common modls	20.0	2.3	.8			
		-Human oper models	20.0	2.3	1.1	27.5	2.9	.9
		-User intrface	26.5	2.4	.8	9.5	2.5	1.0
	Automtd Scenario Genera- tion and Control	-Data bases	26.5	2.4	1.1	27.5	2.9	1.0
		-Expert systems/ neural nets	32.5	2.5	1.0	18.0	2.7	1.0
		-User interf	38.0	2.6	.8	27.5	2.9	1.1
	Expert Systems	-Intel agnts	20.0	2.3	1.0	9.5	2.5	1.3
		-Reusbl	32.5	2.5	.5	22.0	2.8	1.2
		-Scenrio control	32.5	2.5	1.0	27.5	2.9	1.3
		-Knowldg rep	42.0	2.7	.8	38.5	3.2	1.2
		-Instr pedago- gical knowldg modeling	50.0	2.9	1.0	45.0	3.3	1.1
		-Knowldg acquis.	50.0	2.9	.6	45.0	3.3	1.2
		-Infrnce	50.0	2.9	1.2	45.0	3.3	1.3
		-Test case perf	56.0	3.0	1.0	62.0	3.7	1.2
		-Docmnt	60.0	3.1	1.0	45.0	3.3	1.3
		-Expln.	63.0	3.3	1.0	55.0	3.5	1.4

Key: 1 = Very Critical/Very Knowledgeable
3 = Moderately Critical/Knowledgeable
5 = Minimally Critical/Limited Knowledge

TABLE 5 (Cont.)

DELIVERY METHOD	TRNG TECH	ENABLING TECH	CRITICALITY			COMPETENCE		
			RANK	RATING	STD DEV	RANK	RATING	STD DEV
BROAD DEVEL STRATGS -TECHS TARGET MULTPL DELIV METHODS/ STRATGS & TRNG TECH	Visual /Sens Siml.	-Auto photo data base gen	3.0	1.7	.6	22.0	2.8	1.2
		-High qual low cost image gen	4.5	1.8	.8	14.0	2.6	1.3
		- High qual ligh wt optics, HMD	7.5	2.0	1.2	32.0	3.0	1.5
		-Advnced CRT's & light valves	12.5	2.1	.8	12.5	2.6	1.2
		-HDTV	26.5	2.4	.9	14.0	2.6	1.1
		-Reuse software	1.5	1.5	.7	2.5	2.1	1.2
		-Sftwr dev method	4.5	1.8	.9	2.5	2.1	1.2
		-Envir sim	6.0	1.9	.9	4.0	2.2	.9
		-High perf comp	7.5	2.0	.8	1.0	2.0	.8
		-Nat lng voice recog	20.0	2.3	1.0	22.0	2.8	1.0
		-Distrb proc	50.0	2.9	1.2	14.0	2.6	1.0
		-Laser	56.0	3.0	1.2	33.0	3.0	1.3
		-Auto ISD	56.0	3.0	1.4	62.0	3.7	1.2
		-Ops research	62.0	3.2	.6	65.0	3.9	.7
OVERALL MEANS				2.5	1.0		3.0	1.0

Key: 1 = Very Critical/Very Knowledgeable
3 = Moderately Critical/Knowledgeable
5 = Minimally Critical/Limited Knowledge

The eight Enabling Technologies with the highest overall Criticality ratings (2.0 or less) are listed in Table 6. The eight Enabling Technologies with the lowest overall Criticality ratings (greater than 3.0) are listed in Table 7. The 14 Enabling Technologies with the highest overall Criticality ratings among just the most behaviorally oriented topics are shown in Table 8. Criticality ratings are shown for both the total group of respondents and the subgroup of behavioral respondents, along with associated Training Technologies and Delivery Methods.

Table 6

MOST CRITICAL ENABLING TECHNOLOGIES

TECHNOLOGY	CRITICALITY RATING
- Reusable software (Broad Development Strategy)	1.5 (1.5)*
- Interoperability/correlation (Threat modeling and common data bases; Broad Development Strategy)	1.5 (2.5)
- Automated photographic data base generation (Visual/sensor simulation; Broad Development Strategy)	1.7 (2.5)
- High-quality, low-cost image generation (Visual/sensor simulation; Broad Development Strategy)	1.8 (3.0)
- Software development methodology (Broad Development Strategy)	1.8 (2.0)
- Environmental simulation (Broad Development Strategy)	1.9 (2.0)
- High performance computing (Broad Development Strategy)	2.0 (2.0)
- High quality lightweight optics for HMD (Visual/sensor simulation; Broad Development Strategy)	2.0 (3.0)

* The ratings in parentheses are associated only with the behavioral respondents.
Key: 1 = Very Critical; 3 = Moderately Critical; 5 = Minimally Critical

All eight of the Enabling Technologies rated most Critical are Broad Development Strategies and primarily engineering in nature (Table 6). High Criticality found for the Broad Development Strategies is expected, because of their wide applicability across training problems. The higher ratings for

Table 7

LEAST CRITICAL ENABLING TECHNOLOGIES

TECHNOLOGY	CRITICALITY RATING
- Network security (Networking; Multi-player Exercises)	3.1 (3.5)*
- Documentation (Expert systems; Broad Development Strategy)	3.1 (2.3)
- Enhanced lesson and scenario authoring (Training and organizational management; Embedded Training)	3.1 (3.0)
- Head-mounted stereo (Audio displays; Virtual Reality)	3.2 (3.0)
- Operations research (Broad Development Strategy)	3.2 (3.0)
- Explanation (Expert systems; Broad Development Strategy)	3.3 (3.0)
- Automated record management (Training and organizational management; Embedded Training)	3.6 (3.5)
- Coordination and standardization (Training and organizational management; Embedded Training)	3.9 (3.0)

*The ratings in parentheses are associated only with the behavioral respondents.
Key: 1 = Very Critical; 3 = Moderately Critical; 5 = Minimally Critical

the engineering than behavioral technologies is expected because, as noted earlier, the respondents had primarily engineering backgrounds. Differences in perceptions of Criticality between behavioral and engineering respondents are shown by the generally lower Criticality ratings assigned to these items by the behavioral respondents (behavioral respondents' ratings are given in Table 6 in Parentheses). Only two of the eight items -- Reusable software and High performance computing -- received ratings from behavioral respondents equal to the overall group; the remaining six were given moderately to significantly less Critical ratings.

The Competence ratings for the eight most critical Enabling Technologies also are high: five are among the top six in Competence ratings among all 65 Enabling Technologies, and all eight have ratings within the upper quadrant of the Competence scale.

TABLE 8

MOST CRITICAL BEHAVIORAL ENABLING TECHNOLOGIES

TECHNOLOGY	CRITICALITY RATING
- Head-mounted, low cost visual displays (Visual displays; Virtual Reality)	2.1 (3.0)*
- Teamwork skills management (Team performance measurement system; Team Training)	2.3 (1.5)
- Training evaluation measures (Team performance measurement system; Team Training)	2.3 (1.5)
- Intelligent agents (Expert systems; Broad Development Strategy)	2.3 (1.7)
- Intelligent agents (Automated instructional support; Embedded Training)	2.4 (2.0)
- User interface (Threat modeling and common data bases; Broad Development Strategy)	2.4 (2.5)
- Exercise development (Team training system; Team Training)	2.5 (2.0)
- Team training strategies (Team training system; Team Training)	2.5 (1.5)
- Scenario control (Expert systems; Broad Development Strategy)	2.5 (1.7)

*Ratings in parentheses are associated only with the behavioral respondents.
Key: 1 = Very Critical; 3 = Moderately Critical; 5 = Minimally Critical

The eight Enabling Technologies with the lowest Criticality ratings (Table 7) also are among the lowest in Competence ratings, with ranks ranging between 38.5 and 65 out of the 65 Enabling Technologies. Lower Competence ratings might be expected for the five topics that relate to Expert Systems and Embedded Training, since these areas were defined from behavioral science viewpoints and, again, only three of the 18 respondents were human factors specialists. Differences in perception of Criticality between behavioral and engineering respondents are shown by the generally higher Criticality ratings assigned to these items by the behavioral respondents (behavioral respondents' ratings are given in Table 7 in parentheses). Only one of the nine items, Network security, received a lower rating from the behavioral respondents. But, except for Documentation (for Expert systems) both the total group of respondents and the behavioral subgroup rated these items lower than the overall average for Enabling Technologies (2.5). Once again, the respondents' competence with an area should be considered when evaluating Criticality ratings.

Enabling Technologies with strong behavioral orientations are treated separately, because of the dominant engineering orientation of the raters and the low Competence ratings assigned to these items. The nine top rated behaviorally oriented Enabling Technologies have Criticality ratings ranging between 2.1 and 2.5, and mainly support the Team Training and Expert Systems Delivery Methods (Table 8). Once again, differences between engineering and behavioral perceptions are noted, with the behavioral respondents ratings being higher on seven of the nine items, the two exceptions being Head-mounted, low cost visual displays and User interface.

VALIDITY ISSUES

Efforts to assess potential benefits to be derived from new training technologies, such as the current survey, are limited by a lack of laboratory and field evaluations on the value of training technologies in general and the new technologies in particular. Such evaluations should be comprehensive and can be costly.

Criteria for a comprehensive assessment are identified by the NAVPERESDEVCEN-NAVTRASYSCEN Plan (1992). The criteria are subsumed under four categories: (a) "Foundations" -- the fundamental ability of the technology to benefit the Navy; (b) "Affordability Factors" -- the costs associated with realizing the benefits; (c) "Training Situation Applicability" -- the range of situations where the technology can be used; and (d) "Risks" -- barriers to the successful implementation of the technologies (Appendix B). Technology surveys should consider all such factors, but a suitable data base upon which to base such considerations has yet to developed.

CONCLUSIONS

GENERAL IMPLICATIONS

This survey identifies and defines 91 training technologies that are suitable topics for military R&D programs. The major finding from the survey is that training experts -- high level scientists and managers from private industry and the NAVTRASYSCEN -- consider most, if not all, of these technologies important topics for future R&D. A review of related efforts to define training technology priorities for R&D showed a high degree of similarity with the current results.

Additional confirmation for the priority of the technologies is the fact that senior research personnel at the NAVTRASYSCEN were specifically directed to identify the highest priority R&D issues; and the training experts who reviewed and critiqued the survey generally agreed that the survey contained the highest priority R&D issues.

The current survey shows high priority for the technologies by the finding that, across all 91 survey topics, 80 (88%) were rated as Moderately Critical to Very Critical. These are considered especially high ratings because of the nature of the rating scale: a "Very Critical" rating required an extremely high evaluation, which would tend to shift all ratings toward the low end of the scale.

Behavioral topics were expected to receive lower Criticality and Competence ratings than engineering areas, because of the predominantly engineering backgrounds of the respondents. Although these expectations were confirmed, behavioral issues still received high Criticality ratings. This may be attributed to both the broad perspectives of the raters and the importance of the behavioral topics. As expected, behavioral areas received higher ratings from the behavioral respondents.

The extent to which the respondents' familiarity with an area influenced the criticality ratings is not entirely clear, but some such influence is apparent. This suggests that the overall group priorities given to the behaviorally oriented Technologies should be considered conservative estimates, at best. So, the current survey is viewed as a fair measure on engineering issues, but a nonrepresentative, and probably conservative, measure of expert opinion on behavioral topics. For that reason, efforts to make fine priority discriminations based on the ratings may be justified for engineering areas, but are probably inappropriate for the behavioral topics. The following discussion should be considered with this in mind.

The survey could be improved by increasing the number of raters, and particularly increasing the percentage of raters in behavioral disciplines. Then, ratings could be considered across all raters for all areas; but the most valid conclusions might result from considering the ratings only where Competence is high.

The survey could be improved by offering more explicit criteria upon which to base the ratings, such as identified in the NAVPERESDEVCEN-NAVTRASYSCEN Plan (Appendix B). Surveys, and all other efforts to assess training technology, require better information from systematic, empirical, performance-based evaluations of the technologies. Surveys, such as the current effort, give relatively quick answers to critical questions, and the answers may be the best available, but they should be continually validated with the more objective approaches to support a training science.

DELIVERY METHODS

Team Training and Deployed Training, tied for highest Criticality ratings, share top priority. Multi-Player Exercises, third highest in Criticality, is the third highest priority. Virtual Reality follows with fourth priority. The Training Technologies and Enabling Technologies supporting these high ranking Delivery Methods also received high Criticality ratings.

The high Criticality ratings given to the two team training topics shows strong support for team issues, and suggests that highest priority should be given to team issues in general.

Emulation and Embedded Training tied for fifth in priority levels. Interactive Courseware rated seventh in priority. All seven of these Delivery Methods have ratings of Moderately Critical or higher.

The remaining two Delivery Methods -- Wargaming on Ranges with Operational Equipment and Low Cost PC Applications -- received ratings slightly less than Moderately Critical and tied for lowest priority.

Interactive Courseware and Low Cost PC Applications, ranked low by the total group, ranked high in the ratings from behaviorally oriented respondents. This suggests that, while engineering issues are less urgent in these areas, major behavioral issues remain.

TRAINING TECHNOLOGIES

Training Technologies with the highest Criticality ratings also support the highest rated Delivery Methods, or else give broad support across a range of technical areas.

The two Training Technologies with the highest Criticality ratings are Visual/Sensor Simulation and Carrier Based Weapon System Trainer, in that order. Third highest is shared by four Technologies: Visual Displays, Networking, Team Performance Measurement Systems and Team Training Systems.

The remaining 11 Training Technologies also have high Criticality ratings (above Moderately Critical), that recommend them as R&D issues. One possible exception is Training and Organizational Management; but this is a behavioral item, and probably not appropriately represented by the data.

As expected, the behavioral respondents rated behavioral areas higher than the total group ratings. Team training Technologies clearly lead in the ratings, followed closely by Expert Systems and Automated Scenario Generation and Control.

ENABLING TECHNOLOGIES

The bias in the sample of raters appears to have had the strongest influence on the Enabling Technologies. All eight Enabling Technologies shown in Table 6 have strong engineering orientations, and all eight rank highest in Criticality ratings from among the 65 Enabling Technologies. The dominant discipline is less obvious for some of the Enabling Technologies rated lowest in Criticality, but six of the eight rated lowest were defined with strong behavioral perspectives. The two exceptions are Network security and Operations research (Table 7).

Competence ratings also are lower for the six behavioral items rated lowest in Criticality and higher for the eight engineering items rated highest in Criticality. Again, Criticality ratings for the behavioral items should be considered conservative estimates, at best.

Differences in perceptions of Criticality between engineering and behavioral respondents were shown by lower Criticality ratings from the latter compared with overall group ratings for the high rated engineering Enabling Technologies; and higher ratings from the behavioral respondents compared with overall group ratings for both high and low rated behavioral Enabling Technologies.

A large majority of the Enabling Technologies (57 of 65) have Criticality ratings ranging between Very Critical and Moderately Critical. This supports the conclusion that most or (considering the sampling bias) all survey topics are high priority areas for R&D.

All eight Enabling Technologies rated highest in Criticality support a wide range of technical areas (i.e., they are Broad Development Strategies).

Behavioral Enabling Technologies with the highest Criticality ratings (2.1 through 2.5), while lower than the highest rated engineering counterparts (1.5 through 2.0), are still considered strongly recommended for R&D.

Enabling Technologies that support the highest rated Delivery Methods had high Criticality ratings themselves. This indicates that these Technologies are important elements of the Delivery Methods.

RECOMMENDATIONS

- Consider all technology areas identified in the STTS for development and implementation.

- Prioritize selected topics for R&D based on findings presented in this report together with the benefits, costs, risks, and applicability of particular technical developments. Consider criteria such as described in the NAVPERESDEVCEN-NAVTRASYSCEN Plan (Appendix B) to help guide this process.

- Improve Navy research and test facilities to better evaluate promising technologies.

- Improve evaluations of fielded training systems to assure their proper use and cost effectiveness.

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COORDINATION

The STTS began when Mr. H. Okraski tasked the NAVTRASYSCEN Research and Engineering Department's Science Advisory Board (SAB) to identify and prioritize future training technologies and methodologies. This initial effort was expanded into the STTS and distributed to other NAVTRASYSCEN personnel. It was also distributed to personnel from private industry through the auspices of the National Security Industry Association (NSIA) R&D Subcommittee (POC: Dr. James L. Davis) and the American Defense Preparedness Association (POC: Art Banman). Persons who developed, reviewed, and responded to the STTS are listed in Appendix D.

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APPENDIX A

TECHNOLOGIES IDENTIFIED AND RECOMMENDED FOR FUNDING IN THE TRAINING-2000 REPORT

4.0 PROMISING TECHNOLOGIES

The simulator industry takes advantage of existing, new and emerging technologies in the design of training systems. Industry is strongly encouraged to use commercially available hardware and software in an effort to minimize life cycle costs. There are several industry-wide technologies that are ready for exploitation in simulation and training. The task force has identified the following:

INDUSTRY-WIDE TECHNOLOGIES

a. Artificial Intelligence/Expert Systems

b. Improved Visual Displays (Out-The-Window, Helmet-Mounted, Projection Systems and High Definition Television)

c. Modular/Reusable Software and Hardware

d. Software Tools

e. Advanced Computer Architecture

f. Low-Cost Computers

g. Database Generation/Correlation/Fusion

h. Networking

i. Fiber Optics

j. Telecommunication Satellites

What follows are training simulator-peculiar technologies that are ready for exploitation through applied research and demonstration.

SIMULATOR TECHNOLOGIES

a. Threat Models

b. Embedded Training Signal Generation

c. Automated ISD Tools/Documentation

d. Scenario Production Systems

e. Automated Trainee Performance Measurement

f. Training Effectiveness Assessment Tools

g. Team Training Technology

h. Rapid Visual Database Construction/Modification

TABLE I

Recommended Research Issues and Required Funding

Research Issue	Required Funding
Build Navy Training Requirements Simulator	$8 M/yr.
Expand Research for Mission Planning, Mission Rehearsal, Team Training	$6 M/yr.
Expand Research for Embedded Training	$5 M/yr.
Expand Research for Visual Imagery and Weapons Effects	$5 M/yr.
Expand Research for Computer-Based Classroom Training	$3 M/yr.
Expand Research for Instructor/Operator Systems and Standard Software	$4 M/yr.

APPENDIX B

MAJOR CONCLUSIONS FROM THE NAVPERSDEVCEN-NAVTRASYSCEN PLAN

Table I
Connections among Trends, Training Requirements, and Training Technologies.

Trend	Requirement	Technology
Change in missions	Train for new missions...	Warfare/Tactics Simulation
Change in weapons technology	...against new weapons...	Platform simulation
Jointness	...with other Services	Interoperability
	What to train?	Task/cognitive analysis
Quick-response requirement	Develop simulations rapidly.	Authoring aids
	Deliver training rapidly	Networks/Distributed training
	Counter skill degradation	Deployable simulation
	Up-to-date training content	Authoring Aids/Curriculum database
Reconstitution	Scale up rapidly	Networks/Computer delivery
		Distributed training
		Management Tools
Are we ready?	Measure proficiency...	Performance assessment
Is training effective?	...and knowledge	Cognitive assessment
Fewer People	Widely available cross-training	Networks/Distributed training
		Computer-delivery
	Reduce skill/knowledge loss	Cognitive analysis
Reduce shore infrastructure	Develop and deliver...	Authoring aids
	...training more efficiently	Networks/Distributed training
		Improved Instructional Processes
Fe' 'er Dollars	Re-use training	Networks/Computer delivery
		Curriculum Databases
	Improve training management	Networks/Management Tools
	More effective training	Cognitive analysis
		Context-based training
More complicated systems	Increase understanding	Cognitive analysis
		Context-based training
New information displays	Include in training	Simulation
		New delivery media
Deficits in Entering Skills	Where to start?	Cognitive analysis
	Counter low literacy	New delivery media

Table II
Investment Criteria

FOUNDATIONS

Maturity: The extent to which the technology can be implemented. High maturity indicates that procedures and rules for implementation are well defined and systems/devices for delivery are available. Low maturity indicates that the procedures are not fixed, well defined, or operationalized.

Research Base: Indicates the amount of relevant supporting research. For a "high" rating many studies and synthesis of their results indicate how and why the technology works.

R&D gain: Amount of gain (uncertainty reduction) expected from research. A "high" rating indicates that successful R & D would increment evidence about the technology design concept substantially.

Military "Uniqueness": Degree to which the technology is specific or critical to the military, so that development should be accelerated. Technologies with large commercial markets will be developed regardless of Navy funding.

AFFORDABILITY FACTORS

R&D Costs: High "affordability" indicates that the R&D needed to develop the technique for practical use is relatively inexpensive. This is a factor important for deciding whether to support validation demonstration of the technology. "Low affordability" indicates that cost would be high.

Development Costs: Affordability of development refers to the the costs of developing changes and/or additions to the existing training to implement the technology. This includes development of revised training used with the method or technology, and would normally be funded with O&M.

Capital Costs: Refers to the one-time capital investment required to implement the method or technology. This would normally be funded from a procurement account.

Life Cycle Costs: The ability of the system to bear the cost of maintaining the currency of the developed technology to preserve the initial investment.

TRAINING SITUATION APPLICABILITY

Residential Instruction: Usefulness of the technology for primary instruction. How useful would it be for main-line conventional training.

Distributed Training: Usefulness of the technology for training distributed to remote locations, such as deployed personnel, or reservists.

Remedial Instruction: Suitability for repairing deficits in student learning.

Fundamental skills: Usefulness of the technology for fundamental skills training. Fundamental skills are those that are assumed by Navy training materials and jobs, including: skills needed to understand text and manuals; skills needed to find and organize information; skills needed to communicate work related information; calculational skills needed to perform on-the-job.

Military Orientation: Suitability of the technology for familiarization or orientation training.

Continuing professional/technical military education: Suitability for continuing education.

Problem Solving: Usefulness of the technology for enhancing problem solving skill.

Transfer to Real-World: Likelihood that what is learned will transfer to job-tasks.

Group performance: Usefulness of the technology for group or team training. Can the technology be used to integrate skilled performance at team, unit, battle-group, force, or theater levels.

Skill Development: Applicability of technology to support practice to hone skill and develop "warrior's edge".

Skill Maintenance: Utility of the technology for reducing perishability of skill during periods of non-use.

RISKS

Susceptibility to Effectiveness Measurement: Can the effects of the technology be determined. Do there exist suitable measures of effectiveness that the technology is expected to impact.

Acceptability: Political acceptability. Whether the training system would foster the change or resist or ignore it, allowing it to die. Do sponsors and/or decision makers approve the technology in spite of cost?

Momentum: Perceived enthusiasm for implementation by the staff, for staff training, changes to physical plant, acquiring hardware, etc. A "low" rating includes perceived changes to content, staffing, and physical plant that seem too hard to accomplish.

Probability of Success: The probability that implementation of the technology will successfully achieve the goals set for it.

Sustainability: Whether or not the technology, once implemented in the Navy, would be kept running without significant change, or whether regression to older systems is likely.

Table III
Training Systems Technologies

Note: This table contains a detailed list of R&D topical areas. The technologies are grouped into the categories of delivery technologies, instructional processes and methods, and supporting technologies.

DELIVERY TECHNOLOGIES:

Paper-Based Instruction: Techniques to improve paper-oriented instructional materials to improve their effectiveness in skill/knowledge acquisition. Examples are: text format, addition of color or graphics, enforcing readability formulas in text, additions of headings, simplifying text, improving access to information, etc. This area of technology includes using computer programs to apply these techniques automatically.

Drill & Practice Systems: Repeated presentation of questions potentially accompanied by to-be-learned material, often used in circumscribed domains with large numbers of facts or calculations. Usually computer mediated.

Frame-based CBI: Presentation of text, graphics, or video screens of to-be-learned material, with the learner advancing in the material to points where test items may be presented. Frame-based CBI is entirely pre-programmed during instructional development.

Video Games: Systems built to provide practice environments for detection, motor-skill, device-control tasks, and for exploration of unfamiliar environments. Other learning tasks can be embedded in the game.

Scenario-Based Simulations: Scenario-Based Simulations are often but not always implemented on computer systems. The scenario provides the context for the learner to perform a series of actions to accomplish a task/mission/goal. Unlike freeplay discovery scenarios are usually guided.

ICAI: Intelligent Computer Aided Instruction. In contrast to memorization approaches, students explore and interact with an instructional program highly tailored to a knowledge base so that students are offered more extensive feedback and guidance in learning a complex domain. Programs for generating instructional interaction, rather than pre-programmed instruction, are included.

Interactive Video: Standard IV often involves presentation of sequences from a video disk, CD-ROM, or other device to accompany or enhance a computer based instruction program. Emerging enhancements involve accessing large amounts of text or graphics stored on the media, often with database features allowing cross linking of information.

Equipment Simulations: A physical device is represented by computer programs designed to train an individual how to operate or maintain the device. The learning transfer of skills and concepts from the simulated to the actual device may or may not require high fidelity depending upon the focus of the training.

Multi-user Simulation: Same as previous, except several individuals use networked consoles to interact with the simulation concurrently.

Conceptual Simulation: Simulations without high-levels of physical fidelity, but which represent processes or events at conceptual or symbolic levels.

Embedded Training: Training provided by simulation and/or stimulation capabilities built into or added onto operational systems and consoles.

Platform Simulators/Training Devices: These are typically hardware devices that are designed to train explicit job-related objectives. Simulations are built to mimic operational platforms, but with very high visual and physical fidelity, e.g. flight simulators.

Virtual Environments: Use of interactive computer graphics and other computing, display, and sensor technologies to create the illusion of being and operating in a different environment. The technology uses a head-mounted visual display with different views for each eye for 3-D viewing, stereo sound, and gloves with embedded sensors to convert hand motion into computer control.

Electronic classroom: Electronic classrooms are integrated collections of devices that, to varying degrees, provide development, presentation, and management of instructional materials to groups of students. Capability exists for presenting the materials in a variety of media formats, testing the students, and providing summarized information to the instructor on a real-time basis.

Virtual Classroom An electronic "classroom" as described above, except students and instructors are not physically co-located. Instead they are connected via data networks.

Distributed Interactive Simulation: Platform simulators (and perhaps operational platforms with embedded simulation capability) linked via data networks with each other, so that several individuals or teams can be trained in multi-platform interaction. May be applied at various levels of aggregation, e.g. crew, platform, group, force, theater.

INSTRUCTIONAL PROCESSES AND METHODS:

Instructor Training: Techniques to improve the delivery of course content, content knowledge, management skills and testing skills in the classroom, and techniques for enhancing instructor ability to handle one-on-one interaction, including diagnostic skills, tutoring.

Instructor Evaluation: Techniques/system to enhance instructor teaching skills by providing systematic feedback, regarding teaching performance, from students and training managers.

TQL/TQM: A set of practices and process analytic methods to continuously improve the quality and productivity of Navy schoolhouse training. The focus is from management to staff on continuous improvement. Examining difficulties in student learning, student throughput, and providing corrective feedback to instructors.

Student Learning Strategies: Techniques for enhancing basic study skills, such as, concentration management, study time management, notetaking and listening, memory aids, and test taking.

Cognitive Learning Strategies: Training in metacognitive strategies for encoding, reorganizing, manipulating information to increase its utility in problem solving, or its memorability, or transfer value.

Progress Testing: Testing to monitor student's performance after each unit or sub-unit of instruction. Progress testing usually is concerned with declarative knowledge.

Diagnostic Testing: Testing that maps the student's performance onto the procedural, conceptual and knowledge goals of the training to discover instructional or learning shortfalls.

Adaptive Testing: Testing based on estimates of item difficulty according to various mathematical models. Usually administered by computer.

Cooperative Learning: Cooperative learning is the instructional strategy that has more than one student working together for skill or knowledge acquisition. This can be accomplished with or without automated aids, depending on the setting. In Navy environments, cooperative learning has been used effectively by having 2 or 3 students working on the same material at one computer terminal.

Peer Teaching: Augments the instructor through the use of students at similar levels of learning to teach each other in one-on-one situations. The need to become the instructor increases student motivation and the number of repetitions of the lesson.

Goal setting: Goal setting involves establishing specific criteria for length of study or practice or level of performance. They can be applied individually or to groups (see cooperative learning). Effectiveness is enhanced when goals are set appropriately for each student.

Extrinsic Motivation: Extrinsic motivational techniques provide reinforcement that is external to the instructional process/content. Examples are time off from training, a promotion for good performance, a plaque for being best student, choice of duty assignment etc.

Competition: Competition is a motivational technique that may be built into a study task on either an individual or group basis. This strategy usually involves a score based on time-to-complete and/or performance.

Context-Based Training: Context-based training incorporates a variety of techniques and methods that all involve training in a job like environment. The technology assumes that learning is enhanced when instruction focuses on the specific situation in which performance is to occur. This allows the student to learn by doing and understanding the purpose of the particular task at hand in relation to the overall goal of instruction. Thus, the student learns to put the information, facts, situations, and performance skills together in appropriate contexts. Some of the techniques have been used in educational situations where there is no specific job. In these cases, the strategy has been to embed the instruction in realistic (real world) problems or cases. Context-based training contrasts with more traditional instruction which typically focuses on formal, general knowledge and skills abstracted from their uses and taught as isolated topics and rules. Context-based training forms the basis of many current instructional techniques including: anchored instruction, situated cognition, cognitive apprenticeship, functional context training, work models, and the case study method. (Note: military technical research has shown context-based training to result in lower attrition and setback rates, reduced training time, superior on-the-job achievement, retention, and transfer.)

Freeplay Discovery: Freeplay Discovery promotes learning by allowing students to freely explore an environment to discover the laws/rules/principles that govern it. Students learn cause and effect relationships by manipulating variables in the environment. Most of the environments that have been develop by researchers have been implement on computer systems. Some examples, include microworlds for economics and electricity developed at LRDC, as well as Frederickson and Whites' work in electricity.

Mental Model Building: Mental Model Building is the technique of providing students ways of thinking about systems/devices/environments that allow them to diagnose, predict, explain, and reconstruct. Students learn mental models through analogies, structural and functional explanations and examples, informal qualitative reasoning training, imagery techniques, and exploration of actual and/or simulated systems, devices, or environments.

Learning Styles: This technique involves selecting different instructional approaches/delivery methods based on a student's individual learning style. For example, one person may learn more effectively from a video presentation than from a text presentation.

Motivational Gaming: Learning cast in a competitive form of accumulating points or "beating the clock" to achieve correct performance, often with novel interfaces that simulate or represent a learning domain, sometimes in fantasy form. Gaming techniques can be used to add motivational variables to frame- or drill-type instruction to improve interest and persistence in learning.

Overlearning/Automaticity: This strategy is where repeated learning activities are provided such that the student "overlearns" the skill to a high degree and the learned behavior becomes automatic, given the appropriate stimulus setting. That is, the student can perform the activity with very little or no cognitive involvement.

Informal reasoning: Problem-solving based on contextual knowledge as opposed to formal systems. Learner explores/experiences a problem situation with appropriate feedback.

SUPPORTING TECHNOLOGIES:

Cognitive Analysis: Design/development of instructional interventions via task analysis procedures which involve specifying the cognitive or mental events or processes students must acquire, rather than mere observable behaviors. Includes specifying mental models or analogies appropriate for instruction. The process includes techniques for characterizing the knowledge/skill of job experts, representing it in some description language, and describing higher level structure among knowledge elements.

Cognitive Assessment: Techniques for determining the degree to which people have acquired particular cognitive capabilities and processes.

Analysis of Distributed Cognition: Processes for characterizing the nature of cognitive performance on tasks spread over groups of people and other computational devices. Includes techniques for representing the information interfaces among people and devices, the stability of performance over time, redundancy, robustness under uncertainty, and error recovery.

Team Decision Making: Characterization of time-based decision making, including decision making under stress.

Analysis/facilitation of Team Behavior: Includes work on leadership, role-modeling, team organization, computer-supported cooperative work, conferencing.

Automated Aids for Designing Instruction: Computerized tools and decision aids for designing instructional systems. Includes task analysis, media selection, etc. Includes database tools for maintaining relationships between training goals, instructional events, performance measurements, training equipment, etc.

CBI Authoring Tools/Templates: Predefined instructional strategies that accept content from instructor and generate training interactions with students.

Simulation Authoring: Higher level languages/systems/aids for programming simulations.

Scenario Authoring: Higher-level languages/tools for building scenarios, especially for team training and performance assessment.

Automated Performance Measurement: Includes techniques for assessing and recording performance. Advanced techniques include cognitive diagnosis, assessing performance over time.

Automated Performance Measurement for Teams/Units: Includes technologies for assessing the performance of groups with respect to a shared task.

BioPsychometry: The use of advanced technologies for measuring the physiology of brain/cognitive events to understand learning and performance, and to develop performance assessment methods.

Missing Team Member Simulation: Automated replacement of other team members to provide interaction to a trainee.

Stimulation for Embedded Training: Techniques for injecting signals/signatures of simulated adversaries into operational equipment.

Embedded Training Safety/Operability: Includes positive mode selection (e.g. training vs operational), fail-safe technologies.

Mathematical Models and Databases for Simulation: Includes work to model environments, vehicles, and weapons for platform and distributed interactive simulations.

Threat Modeling: Math models and databases for adversaries' platforms, weapons, tactics, and operator behavior.

Intelligent Opponent Simulation: Use of AI-based techniques to provide appropriate adversary behavior during simulation. This may be attempted at the platform level, or at higher levels, such as developing intelligent autonomous forces in a theater-level simulation.

Networking Technology: Technologies for connecting similar and heterogeneous simulation systems. Includes development of computational architectures, data-transmission protocols, compression and encryption techniques.

Instructor Control/Management of Simulations: Techniques for instructor setup of simulations and scenarios, data abstraction and representation for scenario management, instructor situation assessment, recognition of tactics and strategies.

Display Technology: Technologies for displaying simulated environments, including techniques for increasing brightness, resolution, color range/balance, field-of-view, power consumption, transportability.

Head-Mounted Display Technology: As above, but including techniques for 3-D, lower weight and power.

Image Generation: Technologies for modeling and representation of visual images. Issues include resolution, field-of-view, data-rate, data compression and high-rate decompression, data-base generation, construction of real-world models from sensor data.

Audio and Haptic Displays: Includes technologies for audio for sound localization, force generation to stimulate touch.

Transducer and Tracking Technology: Development of devices and processes for sensing position and attitude of trainee's eyes, head, fingers, hands, etc. and for tracking over time. Issues include weight, resolution, stability.

Voice Sensing and Recognition: Technologies for extracting meaning from speech input, including work on phoneme identification/segmentation, higher-level boundary identification in continuous speech, speaker independence.

AI and Expert Systems: Modeling/characterizing intelligent action, knowledge extraction, knowledge representation, inference engines, automated explanation.

Scientific Visualization: Technologies for providing graphical or visual interfaces to complicated data and concepts. For example, probability of detection of a sensor system can be depicted graphically.

Human Factors of Information Display and Control: Technologies for representing data (e.g. for instructors), and for providing control interfaces to simulations and networked systems and scenarios.

Standardization: Control and distribution of training technology, including standards for interoperability of data, multimedia, simulation systems.

Training Systems Design/Development/Support: Includes strategic planning of training technology systems, acquisition policy and standards, implementation and user-involvement strategies, extended profitability/cost/effectiveness studies, human and organizational factors in training technology uptake, logistics and support, maintenance of training quality over time, capability upgrades.

Metrics for Human Performance in Total Systems: Technologies for characterizing effectiveness of human performance and training in terms of total system performance. Models for trading-off investments in system capability vs training or support for human performance.

APPENDIX C
THE SIMULATION AND TRAINING TECHNOLOGY SURVEY (STTS)

CENTER OF EXCELLENCE TRAINING TECHNOLOGY SURVEY

INSTRUCTIONS

The attached survey represents positions held at the Naval Training Systems Center on selected research topics. These positions help define our research and development program. You will find from the survey that our conceptions are incomplete. We invite you to help us refine and extend these conceptions and improve progress in the field by completing the survey. If you cannot complete the entire survey, please return a partial response focusing on items in which you are most competent.

The survey is hierarchical in form, as shown in the figure on page 2. That is, there is a set of Military Training Requirements that require Delivery Methods/Strategies (i.e., approaches for administering instruction), which, in turn, require Training Technologies (i.e., general capabilities required for the delivery of instruction). The Training Technologies require Enabling Technologies (i.e., specific capabilities that support the Training Technologies). These, in turn, have milestones. The objective is to identify the importance/validity of each level in the hierarchy relative to the next higher level. The procedure is given in the following and an example of a completed survey sheet is shown in the table on page 3.

<u>Step 1</u> - RATE CRITICALITY AND COMPETENCE: COLUMN 1

o Using the attached Technology Rating Form and Criticality Scale, please rate (in column 1a) the criticality of advances in <u>each</u> of the Delivery Methods/Strategies* shown in column 1 to Military Training Requirements, exemplified on the front of the survey form. Provide one rating for each Delivery Method/ Strategy reflecting the need for progress in this area of military training. (For example, if you consider progress in Embedded Training "Moderately Critical" for satisfying Military Training Requirements relative to competing Delivery Methods/Strategies of which you are aware, place a "3" next to "Embedded Training" in column 1a).

o Next, use the same form and the Competence Scale to rate (in column 1b) your level of knowledge or competence for each "criticality" rating you have given in column 1a. (For example if you are very knowledgeable about Embedded Training, place a "1" next to Embedded Training in column 1b).

o Comment on "Methods/Strategies" or "Requirements" or add new items in column 5 or any other place on the form, as appropriate.

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* Descriptions of selected Delivery Methods/Strategies and associated technologies ar attached.

INSTRUCTIONS (CONT'D)

o Rate the criticality and your competence for any new items that you contribute, just as for the original items.

<u>Step 2</u> - RATE CRITICALITY AND COMPETENCE: COLUMNS 1 AND 2

Using the same procedures as in Step 1:

o Rate (in column 2a) the criticality of advances in each of the Training Technologies (column 2) to the corresponding Delivery Methods/Strategies (column 1).

Military Training Requirements

(How critical are the Delivery Methods/Strategies to Military Training Requirements?)

Delivery Methods/Strategies

(How critical are the Training Technologies to the Delivery Methods/Strategies?)

Training Technologies*

(How critical are the Enabling Technologies to the (Training Technologies?)

Enabling Technologies

(How appropriate are the milestones to the Enabling Technologies?)

Milestones

Hierarchical Structure of Survey

* Four Training Technologies--Threat Modeling & Common Data Bases, Automated Scenario Generation & Control, Expert Systems, and Visual/Sensor Simulation--use a broad development strategy & are not associated with particular Delivery Methods/Strategies.

TECHNOLOGY RATING FORM

1 Delivery Methods/ Strategies	1a	1b	2 Training Technologies	2a	2b	3 Enabling Technologies	3a	3b	4 Milestones	5 Comments
Embedded Training	3	3	Training & Organizational Management	4	4	Enhanced lesson and scenario authoring	4	4	1995: Develop a prototype tool for automated scenario authoring 2000: Develop a general tool for automated scenario authoring	
						Automated record management	5	5	1995: Develop a framework & plan for Navy-wide automated record ET management system (possibly modeled on Air Force's) 2000: Implement a Navy-wide automated ET record management system	Emphasis should be on use of records
						Coordination & standardization	5	5	1995: Identify & investigate factors necessary to coordinate & standardize 2000: Develop guidelines necessary to coordinate & standardize	
			Automated instructional support	2	3	Automated performance measurement & feedback	2	3	1995: Implement guidelines 2000: Implement capability in fielded systems	1995 guideline unrealistically early
						Automated adaptive instruction	2	4	1995: Implement guidelines 2000: Implement capability in fielded systems	
						Missing team member	1	2	1995: Method for auditory feedback 2000: Non-auditory methods	We have a major R+D effort in this area
						Intelligent agents	4	3	1995: Develop requirements for intelligent platforms in all warfare areas 2000: Develop authoring system(s) for intelligent platforms	
			Engineering technologies	1	3	System stimulation	2	4	1995: Identify issues critical to stimulating actual equipment (AE) 2000: Implement Navy-wide guidelines for stimulating AE	Critical to ET

EXAMPLE OF A COMPLETED SURVEY SHEET

INSTRUCTIONS (CONT'D)

o Rate (in column 2b) your competence for each criticality rating.

o Comment on Training Technologies or add new Training Technologies in column 5 or any other place on the form, as appropriate.

o Rate the criticality and your competence for any new items that you contribute, just as for the original items.

<u>Step 3</u> - RATE CRITICALITY AND COMPETENCE: COLUMNS 2 AND 3

Using the same procedures as in Steps 1 and 2:

o Rate (in column 3a) the criticality of advances in each of the Enabling Technologies (column 3) to the corresponding Training Technologies (column 2).

o Rate (in column 3b) your competence for each criticality rating.

o Comment on Enabling Technologies or add new Enabling Technologies in column 5 or any other place on the form, as appropriate.

o Rate the criticality and your competence for any new items that you contribute, just as for the original items.

<u>Step 4</u> - DEFINE MILESTONES FOR ENABLING TECHNOLOGIES

o Add to or comment on the Milestones (column 4 of the Rating Form) for corresponding Enabling Technologies, as appropriate.

<u>Step 5</u> - DESCRIBE DELIVERY METHODS/STRATEGIES AND ASSOCIATED TECHNOLOGIES

o Comment on the attached technology descriptions, as appropriate. Legible handwritten annotations made directly on the papers are suitable.

o Submit new or revised papers to identify critical research and development areas and issues that we may have missed.

NOTE: WE ARE INTERESTED IN YOUR RECOMMENDATIONS, ESPECIALLY FOR COOPERATIVE EFFORTS BETWEEN PRIVATE AND PUBLIC SECTORS, THAT CAN INCREASE SPONSORSHIP FOR TRAINING RESEARCH AND IMPROVE THE QUALITY OF RESEARCH PRODUCTS.

TECHNOLOGY RATING FORM

NAME____

ORGANIZATION____

POSITION/TITLE____

EDUCATIONAL BACKGROUND____

YEARS EXPERIENCE IN FIELD____

MAILING ADDRESS____

____

PHONE NO.____________________

CRITICALITY SCALE

1	2	3	4	5
Very Critical Progress is more important than for any other capability.		Moderately Critical Progress in capability contributes, but others are more important.		Minimally Critical Progress in capability contributes little to none.

COMPETENCE SCALE

1	2	3	4	5
Very Knowledgeable/ Competent. Have worked extensively in this area. Am competent in this subject.		Knowledgeable. Have some experience in this area. Am familiar with current work.		Limited Knowledge. Have little knowledge in this area.

MILITARY TRAINING REQUIREMENTS (Examples)

- o Develop and maintain proficiency of deployed personnel
- o Reduce TAD (personnel travel) for training purposes
- o Improve mission planning and rehearsal
- o Reduce mishaps from human failure
- o Improve mission success
- o Save training resources
- o Improve battle force operations
- o Improve Reserves training
- o Maintain proficiency of highly perishable skills
- o Prepare for increases in operational complexity
- o Improve command and control

1 Delivery Methods/ Strategies	1a	1b	2 Training Technologies	2a	2b	3 Enabling Technologies	3a	3b	4 Milestones	5 Comments
Embedded Training			Training & Organizational Management			Enhanced lesson and scenario authoring			1995: Develop a prototype tool for automated scenario authoring 2000: Develop a general tool for automated scenario authoring	
						Automated record management			1995: Develop a framework & plan for Navy-wide automated record ET management system (possibly modeled on Air Force's) 2000: Implement a Navy-wide automated ET record management system	
						Coordination & standardization			1995: Identify & investigate factors necessary to coordinate & standardize 2000: Develop guidelines necessary to coordinate & standardize	
			Automated instructional support			Automated performance measurement & feedback			1995: Implement guidelines 2000: Implement capability in fielded systems	
						Automated adaptive instruction			1995: Implement guidelines 2000: Implement capability in fielded systems	
						Missing team member			1995: Method for auditory feedback 2000: Non-auditory methods	
						Intelligent agents			1995: Develop requirements for intelligent platforms in all warfare areas 2000: Develop authoring system(s) for intelligent platforms	
			Engineering technologies			System stimulation			1995: Identify issues critical to stimulating actual equipment (AE) 2000: Implement Navy-wide guidelines for stimulating AE	

1 Delivery Methods/ Strategies	1a	1b	2 Training Technologies	2a	2b	3 Enabling Technologies	3a	3b	4 Milestones	5 Comments
Embedded Training (continued)			Engineering technologies (continued)			System mode conversion			1995: Identify critical factors for conversion from ET to operational modes for selected weapon systems 2000: Implement guidelines for conversion from ET to operational modes for all weapon systems	
						System fail safe			1995: Identify critical factors for maintaining fail safe when system is in ET mode 2000: Implement guidelines for fail safe for all ET applications	
						System safety issues			1995: Identify critical factors to ensure safety of weapon system & personnel during ET 2000: Implement guidelines for safe ET	
Multi-player Exercises			Networking			Environmental parameters modeling			1995: Define critical environmental parameters 2000: Develop environmental models & improve DIS standards	
						Data base & math model development			1995: Define critical data base entities & math model parameters Develop methods & techniques for handling different levels of detail 2000: Develop reusable models & improve DIS standards	
						Data transfer			1995: Determine bandwidth requirements for networked trainers Develop data compression techniques 2000: Improve DIS standard & use techniques in existing training systems	

1 Delivery Methods/ Strategies	1a	1b	2 Training Technologies	2a	2b	3 Enabling Technologies	3a	3b	4 Milestones	5 Comments
Multi-player Exercises (continued)			Networking (continued)			Network security			1995: Develop low cost crypto devices 2000: Use devices in networked training applications	
Virtual Reality			Visual displays			Head-mounted, low-cost visual displays			1995: Monochrome 1000x1000 2000: Color 1000x1000	
			Audio displays			Head-mounted stereo			1995: User specific 2000: Generic use	
			Eye movement transducers			Eye tracking			1995: 5 degree resolution 2000: 1 degree resolution	
			Tactile displays			Force simulation			1995: Finger/hand 2000: Whole body	
Team Training			Team training needs analysis system			Needs analysis survey			1995: Develop/ Refine guidelines for implementing 2000: Implement in new or fielded systems	
						Multiphase analysis of performance			1995: Develop/ Refine guidelines for implementing 2000: Implement in new or fielded systems	
			Team performance measurement system			Teamwork skills measurement			1995: Develop/ Validate prototype human performance modeling measures 2000: Provide guidelines for human performance modeling development 1995: Develop/ Validate prototype critical incidents/ scale development 2000: Provide guidelines for performance measurement development	
						Training evaluation measures			1995: Develop/ Validate prototype training evaluation measures 2000: Provide guidelines for training evaluation measures	

1 Delivery Methods/ Strategies	1a	1b	2 Training Technologies	2a	2b	3 Enabling Technologies	3a	3b	4 Milestones	5 Comments
Team Training (continued)			Team performance measurement system (continued)			Diagnostic mechanisms			1995: Develop/ Validate prototype measures 2000: Provide guidelines for diagnostic mechanism development	
			Team training system			Exercise development			1995: Develop/ Refine principles of exercise development 2000: Provide guidelines for exercise development	
						Team training strategies			1995: Develop/ Refine principles of crosstraining 2000: Provide guidelines for crosstraining development 1995: Develop/ Refine principles of stress exposure training development 2000: Provide guidelines for stress exposure training development 1995: Identify behavioral requirements of effective team leadership 2000: Provide guidelines for team leader training	
						Computer technology			1995: Establish requirements for embedded team training 2000: Provide specifications for embedded team training 1995: Establish requirements for computer-assisted instruction 2000: Provide specifications for computer-assisted instruction 1995: Establish requirements for networked team training systems 2000: Provide specifications for networked team training systems	

1 Delivery Methods/ Strategies	1a	1b	2 Training Technologies	2a	2b	3 Enabling Technologies	3a	3b	4 Milestones	5 Comments
Team Training (continued)			Instructor/ Observer training system			Training delivery			1995: Establish requirements of training delivery 2000: Develop guidelines for training delivery	
						Pre-Training capabilities diagnosis			1995: Establish requirements of pretraining assessment 2000: Develop guidelines for pretraining assessment	
						Task-related/ Team-related guided feedback			1995: Develop/Refine feedback & debrief mechanisms 2000: Develop guidelines for feedback & debrief mechanisms	
Broad Development Strategy - Technologies Target Multiple Delivery Methods/ Strategies			Threat modeling & common data bases			Data sources			1995: Develop process to coordinate access to data sources for weapon system performance & operator behavior 2000: Intelligence agencies fully integrated into threat modeling process	
						Common models			1995: Develop guidelines & standards for user needs, performance metrics, & configuration control 2000: Establish an information clearing house for reusable models	
						Human operator models			1995: Develop guidelines & model structure & selectable skill levels 2000: Develop standard models for several classes of human model applications	
						User interface			1995: Develop guidelines for automated scenario generation, model access & battle management monitor & review 2000:	

1 Delivery Methods/ Strategies	1a	1b	2 Training Technologies	2a	2b	3 Enabling Technologies	3a	3b	4 Milestones	5 Comments
Broad Development Strategy - Technologies Target Multiple Delivery Methods/ Strategies (continued)			Threat modeling & common data bases (continued)			Inter-operability/ correlation			1995: Demonstrate network of dissimilar weapon system trainers with common threat environment 2000: Develop guide-lines for network operation Develop fully coordinated data sets	
			Automated scenario generation & control			Expert systems/ neural nets	•		1995: Implement Automatic Force Stationing for a Battle Group Provide proof of concept demo for automatic track & force movement modeling for multiple ships Determine require-ments for Automatic Instructor Situation Assessment Aid Determine require-ments for Automatic Real-Time Trainee Performance measure-ment & feedback 2000: Implement Automatic Force Stationing for Battle Force Demo automatic track & force movement for blue/ orange Battle Force Demo Automatic Instructor Situation Assessment Aid Demo Automatic Real-Time Trainee Performance Measure-ment & Feedback	

1 Delivery Methods/ Strategies	1a	1b	2 Training Technologies	2a	2b	3 Enabling Technologies	3a	3b	4 Milestones	5 Comments
Broad Development Strategy - Technologies Target Multiple Delivery Methods/ Strategies (continued)			Automated scenario generation & control (continued)			Data bases			1995: Integrate subset of Warfare Tactical Data Base into Automatic Scenario Generator Integrate standard Navy data bases for maps into Automatic Scenario Generator 2000: Integrate entire NWTDS into ASG Re-evaluate current standard Navy data bases for maps & determine if new features can be used	
						User interface			1995: Demonstrate system that permits user to modify an Automatic Scenario Generator knowledge base Demonstrate use of multi-windowing, graphics, menus, to enhance user productivity 2000: Complete system that permits user to modify ASG knowledge base Complete implementation of user interface	
			Expert systems			Intelligent agents			1995: Establish data base of various platform tactics, both friendly & adversary 2000: Establish repository for high quality adversary & friendly platform	
						Scenario control			1995: Develop automatic scenario generator work-station capabilities to reduce time & increase flexibility Develop automatic scenario control software concepts for friendly and/or opposing forces to use intelligent agents & reduce manning 2000:	

1 Delivery Methods/ Strategies	1a	1b	2 Training Technologies	2a	2b	3 Enabling Technologies	3a	3b	4 Milestones	5 Comments
Broad Development Strategy - Technologies Target Multiple Delivery Methods/ Strategies (continued)			Expert systems (continued)			Instructional pedagogical domain knowledge modeling			1995: Develop expert teacher for reuse in various intelligent training systems Develop structure for collection of domain knowledge for training systems 2000: Develop domain independent expert teacher for curriculum development & control Develop standards for achieving domain knowledge of the "best" operators	
						Knowledge acquisition			1995: Develop automated knowledge acquisition system for pedagogical & domain knowledge 2000: Develop domain independent knowledge acquisition system for theater wargaming	
						Knowledge representation			1995: Develop standards for declarative & procedural knowledge representation 2000:	
						Inference			1995: Develop standards for reasoning in expert systems for training 2000: Order of magnitude speed increase in search strategies	
						Test case performance			1995: Develop methods of test case generation for pedagogical expert systems 2000: Develop methods of test case generation for domain expert systems	

1 Delivery Methods/ Strategies	1a	1b	2 Training Technologies	2a	2b	3 Enabling Technologies	3a	3b	4 Milestones	5 Comments
Broad Development Strategy - Technologies Target Multiple Delivery Methods/ Strategies (continued)			Expert systems (continued)			Documentation			1995: Develop techniques for documentation of rules & their interrelationship 2000: Develop automatic debugging tools for knowledge base modification	
						Reusability			1995: Develop techniques for reuse of platforms & tactical rules 2000: Develop standards for expert system shells	
						Explanation			1995: Develop techniques for pedagogical explanation of domain knowledge 2000:	
			Visual/sensor simulation			High quality low cost image generation			1995: 1990 performance at 1/10 cost 2000: PC size & cost with performance limited only by user's vision	
						High quality light weight optics for HMD			1995: Etched plastic wide angle well corrected 2000: Low cost HMD's available to public	
						Advanced CRT's & light valves			1995: 2000 lumen CRT's low maintenance light valves 2000: 2000 line resolution 4000 lumen CRT's low cost light valves	
						Automated photographic data base generation			1995: Texture recognition & semi-automated feature extraction from photos 2000: Neural networks for image analysis & data base generation	
						HDTV			1995: Components designed & ready for marketing 2000: In general use by public & in general use in networking for training	

The following topics are included to stimulate interest in defining additional methods and technologies. Please contribute to these topics and identify additional items, as appropriate.

1 Delivery Methods/ Strategies	1a	1b	2 Training Technologies	2a	2b	3 Enabling Technologies	3a	3b	4 Milestones	5 Comments
Wargaming on Ranges with Operational Equipment										
Deployed Training			Carrier-based weapons system trainer			Miniature displays			1995: 2000:	
						Photo-based image generators			1995: 2000:	
						Reconfigurable low maintenance cockpit			1995: 2000:	
Interactive Courseware									1995: 2000:	
Low Cost PC Applications									1995: 2000:	
Emulation									1995: 2000:	
Broad Development Strategy - Technologies Target Multiple Delivery Methods/Strategies & Training Technologies						Automated ISD			1995: 2000:	
						Operations research			1995: 2000:	
						Distributed processing			1995: 2000:	
						Laser			1995: 2000:	
						Environmental simulation			1995: 2000:	
						Natural language voice recognition			1995: 2000:	
						High performance computing			1995: 2000:	
						Software development methodology			1995: 2000:	
						Reusable software			1995: 2000:	

EMBEDDED TRAINING

DESCRIPTION OF TECHNOLOGY

The Chief of Naval Education and Training, Embedded Training Task Force (1985, Nov.), defined embedded training as "training that is provided by capabilities built into or added onto operational systems, subsystems, or equipment, to enhance and maintain the skill proficiency of fleet personnel" (para 4.1). Embedded training offers a means of providing initial, advanced, refresher, predeployment, and mission rehearsal training at deployed or remote sites.

Embedded training can be configured in various ways to meet specific applications. Embedded training can be fully embedded in the operational equipment, it can be provided by adding on external equipment to the operational equipment (e.g., target generators), or operational equipment can be connected to training equipment with umbilical cables. Whichever form it takes, embedded training usually has the following two characteristics:

a. It uses operational equipment (e.g., consoles, displays, indicators) as the primary training media. Trainee interaction with the operational equipment is required. Operational data, signals, or targets are simulated or stimulated on the operational equipment for operator training. Real world faults, malfunctions, and interferences are simulated or stimulated on the operational equipment for maintenance training.

b. It should include instructional support features to manage the training process since instructors are often unavailable. Automated development and control of training scenarios, control of lesson content, and adjustment of lesson difficulty may be required. A mechanism for trainee performance measurement and feedback is required. Records management and exercise storage functions are often included.

In the past, embedded training has often used engineering test approaches to inject signals into operational equipment. These approaches allow for practice, but provide little training. Only when instructional technologies are included does an embedded <u>training</u> system exist. Many of the instructional tasks conducted by instructors must be automated in embedded training systems because instructors are not available or manning is less than at shore-based facilities. Instructional technologies may be classified into two main categories: those with general applicability to all forms of embedded training, and those with special emphasis on tactical and/or team training.

GENERAL EMBEDDED TRAINING INSTRUCTIONAL TECHNOLOGIES

The following instructional technologies are applicable in all forms of embedded training:

a. Automated performance measurement and expository feedback: monitor the performance of the trainee and provide information about errors and corrective actions. If the trainee is not provided feedback on the quality of his or her performance, little learning can be expected.

b. Automated adaptive instruction: continuously assesses trainee strengths and weaknesses and adjusts the course of instruction to build on strengths and focus on weaknesses.

TACTICAL/TEAM EMBEDDED TRAINING INSTRUCTIONAL TECHNOLOGIES

The following technologies are specific to embedded training for tactics and team applications:

a. Intelligent platforms: make decisions (independent of an instructor) to realistically simulate the maneuvers and actions of both friendly assets and targets during a dynamic training exercise.

b. Missing team member simulation: removes the necessity to access whole teams or subteams when the desire is to training single team members or subteams. Although virtually all training involves team interactions, all members of all teams are not always available for training. Simulating missing team members allows training to proceed and also allows control of the level of expertise of the missing team members.

TRAINING MANAGEMENT AND ORGANIZATIONAL ISSUES

Training development, coordination, and management are important issues in embedded training due to the reduced manning levels of instructors and course administrators, and the diverse locations or embedded training. These technologies fall into three main categories:

a. Enhanced lesson and scenario authoring: provide the capabilities for supervisors or other subject matter experts, who are not training experts, to build and modify training scenarios that will provide realistic, mission-relevant lessons that include the instructional capabilities discussed above.

b. Automated record management: maintains training records of all trainees and makes these records available when needed to evaluate additional training requirements, promotion potential, reassignment potential, etc.

c. Coordination of embedded training: refers to the organizational issues of standardizing and validating the embedded training that is given at various sites. Without such coordination, it is not possible to ensure that: (1) individuals trained at one site will receive the same level of training that was provided at other sites; (2) individuals will be able to continue their training path at alternative sites; or 3) that training deficiencies can be identified and corrected at future sites.

ENGINEERING TECHNOLOGY ISSUES

Even though many of the technologies to stimulate operational equipment with signals, targets, simulated malfunctions, and other functions necessary for embedded training already exist, technologies to maximize the efficiency and quality of stimulation are required. Some of the engineering technology issues include:

a. How to determine at which point in the operational system (e.g., at the display, at the main bus, at the radar dish, etc.) signals should be injected or the system otherwise stimulated.

b. How to ensure that the operational system can be brought out of training mode and back to operational mode quickly and efficiently.

c. How to ensure that embedded training scenarios do not damage or otherwise degrade the operational system.

d. How to ensure weapons safety during training.

e. How to ensure the safety of the ship and crew during training.

f. How to choose between varieties of embedded training (e.g., fully embedded, strap-on, umbilical, etc.).

CRITICAL TECHNOLOGY CHALLENGES IN EMBEDDED TRAINING

o Instructional Technologies

- General Technologies
  - -- Automated Performance Measurement and Expository Feedback
  - -- Automated Adaptive Instruction
- Technologies Specific to Tactical/Team Training
  - -- Intelligent Platforms
  - -- Missing Team member Simulation

o Training Management and Organizational Technologies

- Enhanced Lesson & Scenario Authoring
- Automated Record Management
- Coordination/Standardization of Embedded Training

o Embedded Training System Engineering Technologies

- Stimulation Technologies
- Conversion from Training to Operation Modes
- System Fail Safe Technologies
- Technologies to Ensure Safety of Weapons and Personnel
- Methods to choose Between Types of Embedded Training

MILESTONES

Instructional Technologies

TECHNICAL AREA	BY 1995	BY 2000
Automated Performance Measurement & Expository Feedback	Develop guidelines for implementing	Implement in new or fielded systems
Automated Adaptive Instruction	Develop guidelines for cognitively structuring & adaptively sequencing instruction (with algorithms to be followed)	Implement in new or fielded systems
Intelligent Platforms	Develop IP requirements for all warfare areas	Develop authoring system(s) for IPs
Missing Team Member Sim.	Develop methods to implement for auditory feedback	Develop general methods to implement for other than auditory

Training Management & Organizational Technologies

TECHNICAL AREA	BY 1995	BY 2000
Enhanced Lesson & Scenario Authoring	Develop prototype tool for automated scenario authoring	Develop a general tool for automated scenario authoring
Automated Record Management	Develop a framework & plan for Navy-wide automated ET record management system (possibly modeled on Air Force's)	Implement a Navy-wide automated ET record management system
Coordination & Standardization	Identify & investigate factors necessary to coordinate & standardize	Develop guidelines to coordinate & standardize

Engineering Technologies

TECHNICAL AREA	BY 1995	BY 2000
System Stimulation	Identify issues critical to stimulating actual equipment (AE)	Implement Navy-wide guidelines for stimulating AE
System Mode Conversion	Identify critical factors for conversion from ET to operational modes for selected weapon systems	Implement guidelines for conversion from ET to operation- al modes for all weapon systems
System Fail Safe	Identify critical factors for maintaining fail safe for selected ET applications	Implement guidelines for fail safe for all ET applications
System Safety Issues	Identify critical factors to ensure safety of weapon systems and personnel during ET	Implement guidelines for safe ET

NETWORKING

DESCRIPTION OF TECHNOLOGY

Networking when used in a training context encompasses the interconnection of training systems and operational equipment. Considerable success has been achieved by the Army in networking combat simulators at different geographical locations. For example, the Army can effectively conduct combined arms training using tank simulators at Ft. Knox, KY, networked to helicopter simulators at Ft. Rucker, AL, and Bradley Fighting Vehicles at Ft. Benning, GA. This technology has come to be known as SIMNET (simulator networking). To date the Navy and Air Force have made very limited use of simulator networking.

Simulator networking holds great potential for enhancing tactical team training from small units up to joint service exercises. Networking is the cornerstone technology for the Tactical Combat Training System (TCTS). This battle group trainer will require the networking of simulations running on-board operational platforms at sea and in the air with land based simulations. Simulator networking has the potential to allow the Navy to realize more benefits from its existing inventory of training systems.

Many technical issues must be resolved before heterogeneous trainers can be productively used in a network. The major issues in interconnecting trainers are:

Environmental Parameters. The simulated environments in the various host computers must correlate. There is not even a standard definition of the environmental parameters, much less agreement in their values.

Data Bases and Mathematical Models. The environment,vehicles and weapons systems in a simulation are represented by mathematical models. There is no standard for either the mathematical models or the data bases for the various entities.

Data Rate Limitations. The amount of data that can be interchanged between interconnected simulations is limited. Transmission of large amounts of data is not only costly in terms of equipment, but leads to unacceptable delay in the availability of the data.

Network Security. Much of the data transmitted between trainers in a tactical training exercise is classified. A secure data network must be provided.

The issues associated with these problems are the following:

o How to ensure that the simulated environments in two host computers correlate?

o How well must the environments correlate to produce adequate training? How to handle differences in level of detail between two models?

o How to communicate changes in environment in one host computer to other host computers?

o How to provide low cost encryption and decrypting devices that have minimal propagation delays?

MILESTONES

TECHNICAL AREA	BY 1995	BY 2000
Environmental Parameters	o Define critical environmental parameters o Determine degree of correlation required for adequate training	o Develop environmental models and improve o Distributed Interactive Simulation (DIS) Standard
Data Bases/ Mathematical Models	o Define critical data base entities and math model parameters o Develop methods and techniques for handling different levels of detail	o Develop reusable models and improve DIS standard
Data Rate Limitations	o Determine bandwidth requirements for networked trainers o Develop data compression techniques	o Improve DIS standard and use techniques in existing training systems
Network Security	o Develop low cost crypto devices	o Use devices in networked training applications

Special Report 93-005

VIRTUAL ENVIRONMENT TRAINING TECHNOLOGY (VETT)

DESCRIPTION OF TECHNOLOGY

Virtual Environment (VE) technologies are being developed to provide more efficient and effective interfaces between humans and computers. The motivating premise for developing VE technologies is that existing user-computer interfaces are unnatural and inefficient. Terminal displays and keyboards were adequate for users as long as the other side of the interface, the computer, was slow and/or non-interactive. The terminal-keyboard interface has limited capability in both directions. Almost all the information flowing across the user-computer interface is one-dimensional and symbolic in the form of a stream of alphanumeric characters. The terminal stimulates a small part of only one of the user's sensory systems (vision) and the keyboard is stimulated by a relatively limited set of user mechanical actions (typing). VE technology has the goal of developing natural, multi-modality, user-transparent, human-computer interfaces by providing the user with displays for all of his sensory systems and transducers which can interpret the user's control actions.

Communication in the natural world between a man and his environment is rich and complex. All of his senses are stimulated and there is wide range of possible actions he can use to affect his environment. The existing user-computer interface (in most cases) results in the user perception of observing through a window as opposed to being a participant in an 3-dimensional, interactive, totally experienced environment.

The potential of VE has been recognized by the popular press in feature articles describing "virtual reality," "virtual environments," "artificial reality," "cybernetics," etc. In general, the articles miss the point. They usually emphasize the tools used to enable VE's and exotic applications of the concept. The point missed is that VE is a communications medium. The specific hardware and software tools used by the medium and the specific applications of the medium are not essential to the concept. VE is a medium of communication just as books, telephones, televisions, etc. are communication media.

VE VS. SIMULATION VS. TELEPRESENCE

How does VE technology differ from man-in-the-loop simulation and telepresence? The answer is that the differences are, or at least should be, transparent to the user. Ideally, the user side of the interface is the same in all three technology areas. The interface is such that the user perceives himself to be immersed in an environment. The differences between the three related technologies are on the machine or computer side of the interface. In the case of telepresence, the environment is created by a remotely located machine sensor system, e.g. a remotely piloted vehicle, which is operating in the real world. In the case of man-in-the-loop simulation, the environment is a mix of computer generated and physical representations of a real world operator environment. In the case of VE technology, the environment is totally (ultimately) synthesized by computer. The differences between training simulators and VE are subtle. VE technology is designed to emphasize the user or human side of the interface and, ideally, is independent of the machine side of the interface, e.g., a VE system for pilot training might use the same interface hardware set as a VE system for sonar operator training. Simulation technology emphasizes the machine side of the interface, e.g., simulators designed for F-14 pilot training are not useable for P-3 pilot training. The emphasis of VE technology is high fidelity stimulation of the user's sensory systems. The emphasis of simulation technology is high fidelity modeling of real world, operational hardware. Another distinction is that VE's need not have a real world counterpart. The VE need not be constrained by laws of physics, for example. Whereas simulated environments generally strive to have high fidelity to the real world environment being simulated. Man-in-the-loop simulators are a sub-class of VE's in that some simulator system components, such as the visual display of the extra-cockpit environment in a flight simulator, can be considered to be non-platform specific while other system components, such as flight controls are highly platform specific.

Another premise driving the development of VE technology is that symbolic interfaces (communication by reading and writing) is in itself inefficient and unnatural. The history of communication didn't end with the invention of the printing press. There is no natural law that says that communication media must use alpha-numeric symbols. Communication which involves all of the senses to the limits of their capabilities is both more efficient and more effective. When communication is interactive, the efficiency and effectiveness improves still further. Natural, direct, total sensory experiences are more effective than translating and processing alpha-numeric symbols.

VE's have been and will continue to be developed under many different names. The name is just a concept for unifying and giving direction to diverse developments. Some examples of how developments are progressing toward VE's (without being called VE's) are:

a. Literacy - As media which provide more sensory stimulation become more and more available there is less and less motivation for people to become proficient alpha-numeric symbol manipulators. Primary school students spend and enjoy their time with television and video games much more than newspapers or books. The television and video game media are closer to natural experiences than text. The recently reported multi-year decline in SAT verbal scores may be symptomatic of the trend.

b. Documentation - Historic documentation in textbooks has given way, first to photographs, then to motion pictures and most recently to video tapes. Each stage representing a step toward more natural experiences. The domination of home video cameras over motion picture cameras (despite a loss in image fidelity) attests to the desirability of immediate feedback and user interaction.

c. Desktop Computer Interfaces - The recent surge in popularity of graphic user interfaces (GUI), mouse, joystick, trackball, touch screens, etc., demonstrate the advantages of such devices over alpha-numeric terminal and keyboard interfaces.

d. Visual Simulation Technology - Man-in-the-loop simulators have been going down the road toward VE's for decades. The appearance of the real world has progressed from 3-dimensional scale physical models (terrain boards) or photographs to real time computer image generation (CIG). The loss in image fidelity has been greatly outweighed by the increase in real time interaction and flexibility in training scenarios allowed by CIG. Simulation of operational cockpit displays is progressing from the use of synthetically stimulated actual instruments to simulation of the appearance of cockpit instruments using graphics on a CRT face.

e. Interpersonal Communication - The last major breakthrough in interpersonal communication was the telephone. But, video teleconferencing is considered to have great potential and technical obstacles are being overcome.

VE TECHNOLOGY STATUS

The capabilities of a user to absorb, process and transmit information are large but finite quantities. The development of affordable, high capacity computer systems which can match users' information flow rates is happening now. The time for developing VE systems is ripe.

VE technology can be divided into interface technologies and environment generating technologies. Environment generating technologies overlap to a high degree with simulation technologies and will not be discussed in any detail in this document. The interface technologies associated with VE's are those which have received the most attention in the popular literature. The interface technologies include those which stimulate the user's sensory system (displays, in the generic sense) and those which measure the user's responses (transducers).

DISPLAY SYSTEMS - Displays include visual, auditory, haptic (cutaneous and kinesthetic) and other (smell, taste, etc.). Ideally a perfect VE display would provide sensory stimuli indistinguishable from those provided by real world counterparts of the VE.

a. Visual Displays - The visual displays usually associated with VE's are head mounted displays (HMD). This isn't an absolute requirement. It just so happens that helmet mounted displays are capable of providing the unlimited total field of view, which compels a total immersion experience, at a much lower cost than the multiple projector, full field of view dome visual systems such as those used in flight training simulators. The image quality of the consumer affordable HMD's is now somewhat deficient when compared to that available in a simulator dome visual system, but it suffices (for most observer's) to provide the "suspension of disbelief" necessary for an immersive experience. Commercial head mounted display systems are available off-the-shelf at costs ranging from a few hundred dollars to $15,000. More sophisticated head mounted display systems have been developed for military operational and training simulator applications at costs ranging from $50K to $1M+. The primary performance differences between the low cost commercial systems and the high cost military systems are: military systems are see-through (the computer generated imagery overlays the non-virtual, visible, external environment) while the commercial systems are generally opaque to the outside world (all visually sensed information is provided by the VE); and the military systems generally have higher resolution but smaller instantaneous fields of view. The major problem associated with HMD's is instability of the displayed image caused by the time lag between a head movement and the display of the correct imagery for the new head position.

b. Audio Displays - High fidelity, head mounted stereo systems are commercially available and are being used in laboratories for VE system development. The physical differences between users' hearing sensor systems results in a requirement for individual calibration if the sound localization capability of the user is to be effectively stimulated.

c. Haptic Displays - Providing effective stimulation of the cutaneous sensor system is a relatively new area with lots of room for improvement. Systems which provide forces to fingers, hands and arms have been developed with some success. Cutaneous sensor stimulation systems have been used in simulators in the form of g-seats and g-suits. Stimulation of the kinesthetic senses, which allow the user to sense his own limb position and acceleration is a wide open area for further investigation. Again, training simulators have used motion platforms to provide onset acceleration cues for some time.

d. Other Displays - Stimulating smell, taste and other senses is still at the concept stage.

TRANSDUCER SYSTEMS - Transducers include those required for measuring position and attitude of the user's eyes, head, fingers, hands, arms and other body parts. Other transducers include those required for voice and, eventually, brain or other nervous system electrical emanations/properties.

a. Eye Tracking Systems - An ideal VE visual display system would take maximum advantage of the limitations of the human visual system. The human visual system has its highest resolution capability in its central field. This capability falls off rapidly for the peripheral field. An efficient VE visual display should take advantage of this situation by providing high resolution imagery to the eye's central field and degrade to lower resolution at large off-axis angles. Therefore, in an ideal system, the look direction of the eye must be measured. Eye tracking technology has been under development for many years and there are commercial systems available off-the-shelf suitable for experimentation and laboratory systems. However, there are no systems available which are reliable, affordable and robust enough for use in a consumer product.

b. Head Tracking Systems - Head tracking systems have been under development for decades. The primary application has been helmet mounted sights and HMD stabilization in military weapon systems. More recently the technology has been used in simulator and VE applications. Systems are available off-the-shelf. The performance of such systems is deficient in several areas and better head tracking systems are still required.

c. Hand, Finger Tracking Systems - There are systems available off-the-shelf at costs ranging from $50 to $50,000. Their capabilities range from 2-dimensional hand position (such as a mouse or joystick) to finger position sensors which measure up to 20 variables.

d. Voice Sensing/Recognition Systems - A speaker independent, continuous speech recognition system is a goal which hasn't been achieved. As with many of the other components of VE technology, significant development will be required before a user transparent voice interface is available with the qualities of affordability and reliability. The current state of the art requires individual calibration for anything other than a few discrete words.

e. Other Sensing Systems - There are several other characteristics of the user which can be sensed. However, most of them are involuntary and their utilization in a VE system would be purely speculative.

VE APPLICATIONS

VE technology is a concept. It is a communications medium. It is a tool which facilitates the man-machine interface. As a medium it can be applied to a variety of applications just as print, the telephone, photography, television, etc., have an unlimited number of applications. The application developer's problem is to determine what applications will be accomplished more efficiently, effectively, and affordably with this tool. But, since the tool has the potential for a wide variety of applications, it need not be the best tool for each, or for that matter, any of the applications to justify its existence. Consider a desktop computer system. The desktop is a single system which performs a variety of functions. It could be argued that each function could be performed more efficiently by a dedicated system e.g., word processor, filing system, graphics generation, computer terminal, interoffice communication, facsimile transmission, etc. But no collection of dedicated systems is more efficient for accomplishing all of the applications.

Speculation on the potential applications of VE technology together with some thoughts on a future society based on VE's are listed below:

a. VEHICLE OPERATOR TRAINING - A single VE interface could provide the training environment for any type of vehicle from a car to a high performance aircraft. The more complex the system the more likely this application is viable. A fly-by-wire aircraft with multi-function graphics and head-mounted display environment is conceptually easier to "virtualize" than a bicycle environment (given the current state-of-the-art of haptic displays).

b. TELEOPERATION/TELEPRESENCE - VE technology can be used to provide a more efficient and effective interactive interface between a remote operator and the task being performed. The VE is performing well when the user doesn't know it's there.

c. VIRTUAL OFFICE - All operations associated with business office operation could be carried out in a VE including teleconferencing, telephoning, desktop computer system operation, filing, etc. Eventually, if VE's become as common and affordable as the telephone is today, there would be dramatic reduction in physical commuter travel and business trips.

d. RETAIL BUSINESS - A VE interface to a wide area network would enable virtual shopping, complete with interactive product demonstrations, trying on clothes, etc. Virtual malls. Virtual car showrooms and test drives. Virtual interior decorating.

e. COMPUTER AIDED DESIGN - VE's for design of just about anything are possible. Coupled with advanced computer systems to do all of the calculations and insure obedience to the laws of physics anyone would have the capability to design anything. But, just as a camera doesn't make everyone a photographer, designers will still need education and skills.

f. BUILDING AND CONSTRUCTION - Virtual landscaping. Virtual 3-D plans and blueprints. Virtual site location/new construction impact.

g. TELESOCIALIZATION - Extend the current concept of forums on computer networks with the increased sensory stimulation possible with VE technology and a virtual "common" is a possibility. The virtual common allows multiple participants in a never ending interactive discussion which can be joined or left at any time. Each participant can be seen and heard by the others.

h. RECREATION & ENTERTAINMENT - Virtual theater. Virtual (vicarious) participation in theater, sports, fictitious situations. "Feelies." Virtual vacations.

i. MEDICAL - VE's for paralyzed, blind, crippled, learning disabled, etc. to lessen effects of their handicaps. Virtual surgery for practice, experimentation, pre-operation briefing.

j. EDUCATION - Virtual computer aided instruction. Virtual encyclopedia.

k. SCIENCE/RESEARCH - VE's allow visualization and hands on manipulation and study of all realms of investigation from sub-atomic particles to galaxies.

l. CONNECTIONS - The VE equivalent to the cellular telephone will allow all of the VE applications to be realized in a man-portable implementation.

m. QUESTIONS - As implied by the speculations listed above, a future society based on the a VE medium will have many far-reaching impacts on all phases of society. What will wealth mean when the accouterments associated with today's wealth are available to be experienced in a VE? What will the impact be on the travel industry when there is no need to travel to experience a different location? What are the impacts on energy conservation and environment protection?

CRITICAL TECHNOLOGY CHALLENGES IN VE

VETT OBJECTIVES - The Naval Training Systems Center has started a VE Training Technology (VETT) project to develop and evaluate the application of VE technology to military training systems. Although the potential is obvious, the benefits in terms of cost and training effectiveness must be analyzed and demonstrated prior to the introduction of the medium in military training syllabi. Questions to be addressed by this exploratory development project include: What types of training can be improved, in terms of training cost and/or skill acquisition and retention using VE's? How is an instructional system designed and developed using the VE medium? What technical performance characteristics are required in a VE system for specific training applications? What are the existing VE deficiencies that must be overcome to allow utilization in specific training applications?

VETT APPROACH - The VETT project includes the following tasks:

a. Development of a VE laboratory. This includes a survey of available VE system components and assessment of suitability of the components for the military training application. Also included are visits to existing VE laboratories for discussions and demonstrations which will assist in the laboratory development process.

b. Analysis of existing military training courses to identify and prioritize candidates for improvement through application of VE technology.

c. Demonstrate and evaluate existing VE technology to determine whether the specific training task candidates can be effectively performed in the VE by someone already skilled in the task.

d. Develop/modify/enhance virtual technology components as required to allow task performance for training task candidates.

e. Develop the instructional system design for the candidate(s) chosen for training effectiveness evaluation making maximum use of VE technology.

f. Perform training effectiveness evaluation(s) through comparison of students trained with conventional techniques using the same performance criteria.

g. For those candidate VE training tasks which are demonstrated to be equally or more effective than conventional training, evaluate the cost effectiveness.

h. Transition candidate training systems to field evaluation.

i. As VE technology improves and experience in application of the technology to military training systems grows, iterate the above process and extend to additional training areas while improving implementation on previously investigated training areas.

MILESTONES

Training Technologies

TECHNICAL AREA	BY 1995	BY 2000
Visual Displays	Monochrome, Stereo, 1,000,000 pixels	Color, eye-limited resolution
Audio Displays	User Calib., Azimuth discrimination	User Indep., 2 axis discrim
Haptic Displays	Tactile cueing, force icons	True hand, arm, whole body forces
Head & Eye Transducers	Head - 1 arc min, eye - 5 degree	Eye - 30 arc minute

Enabling Technologies

TECHNICAL AREA	BY 1995	BY 2000
Head-Mounted Displays	Monochrome, stereo, 1,000,000 pixels	Color, eye-limited resolution
Head-Mounted Earphone	User Calib., Azimuth discrimination	User indep., 2 axis discrim
Force Sensing & Generation	Tactile cueing, force icons	True hand, arm, whole body forces
Magnetic & Optical	Head- 1 arc min, eye - 5 degree	Eye - 30 arc minute

TEAM TRAINING

DESCRIPTION OF TECHNOLOGY

Most military tasks involve multiple operators, information exchange and transfer, complex, multi-component decisions, and a fast work tempo. Such a work environment requires team coordination for successful completion of tasks. Team training teaches the skills and techniques necessary for team members to accomplish interdependent tasks as a coordinated unit. Team training technology provides a set of methodologies and instructional strategies to enhance and maintain the operational proficiency and readiness of combat teams. Four support systems are required in order to accomplish development of team training technology: (a) a team training needs analysis system, (b) a team performance measurement system, (c) a team training system, and (d) an instructor/observer training system.

TEAM TRAINING NEEDS ANALYSIS SYSTEM

Team training development must rest on a comprehensive understanding of the team coordination requirements of a given task. The needs analysis survey and the multiphase analysis of performance (MAP) system are examples of task coordination analysis methodologies that are being developed at NTSC as enabling technologies for a team training needs analysis system. These methodologies seek to identify the task-specific teamwork (i.e., coordination) requirements necessary for effective team performance, and form a basis for training development.

Needs Analysis Survey. Development of a needs analysis survey begins with reviews of training materials and team research programs. This process provides background information about behavioral examples of teamwork skills. In-depth interviews with subject matter experts in the training community are then conducted to generate behaviors specific to that community (e.g., aircrews and combat information center operators). A second group of subject matter experts verifies the importance, difficulty, and frequency of occurrence of these behaviors. Finally, a revised survey instrument is given to a larger group of subject matter experts to establish that the interactive skill behaviors are critical to mission effectiveness and important to train in the specific community.

Multiphase Analysis of Performance System. The MAP system is a process by which the type of training situation drives the type of task analysis method to be used. Four unique training situations dictate which team task analysis methodology is most appropriate: (a) team-oriented training for inexperienced teams, (b) team-oriented training for experienced teams, (c) task-oriented training for inexperienced teams, and (d) task-oriented training for experienced teams. Team training needs and objectives are developed from the task analysis.

TEAM PERFORMANCE MEASUREMENT SYSTEM

Viable performance measures are paramount to effective training. With respect to team training, measures must be developed that allow instructors to diagnose the causes of effective and ineffective team performance. These measures also form the basis of feedback and debrief mechanisms. In addition, criterion measures are necessary so that training effectiveness can be assessed adequately. Several technologies are being developed to achieve these goals.

Measurement of Teamwork Skills. Critical knowledge, skills, and abilities (KSAs) for task-specific team coordination are generated from the needs analysis system. Once established, KSAs form the basis for measures of teamwork performance. Specifically, measures of team process can be developed by constructing observational protocols, and by employing human performance modeling technologies (e.g., petri nets). Standards for team performance can also be developed using scaling techniques (i.e., critical incidents).

Training Evaluation. Systematic, objective evaluation of team training systems is required to assess the efficacy of training interventions. Training effectiveness diagnostic mechanisms must be developed in order to expedite incorporation of "lessons learned" into training design. Further, transfer of training, that is, the extent to which training produces desired improvements in the operational environment, must also be assessed. Methodologies that provide a comprehensive assessment of training effectiveness must be developed.

TEAM TRAINING SYSTEM

Research has shown that teamwork performance is critical to mission accomplishment. The goals of team training are to train requisite teamwork knowledge and critical teamwork skills, foster shared task models, and maintain/enhance training motivation. Achievement of these goals can be accomplished through such team training instructional technologies as:

a. Exercise development (e.g., lecture, behavior modeling, role play, simulation/exercises),

b. Team training strategies developed for specific team environments (e.g., crosstraining, stress exposure training, team leader training), and

c. Computer technology (e.g., embedded training, computer assisted instruction, networked systems).

Instructional strategies are designed to provide trainees with information about what they will learn, demonstration of expected skills, opportunities to practice skills, and feedback on training performance.

INSTRUCTOR/OBSERVER TRAINING SYSTEM

The training of instructors and observers is crucial to achieving the team training objectives listed above. Specific instructional technologies for instructor/observer training include: (a) training delivery strategies that include effective use of instructional procedures and assessment instruments, (b) pre-training capabilities diagnosis, and (c) task-related and team-related guided feedback training.

CRITICAL TECHNOLOGY CHALLENGES IN TEAM TRAINING

Current team training systems lack prescriptions about how to compose, manage, and train teams. NTSC research is being conducted to provide principles and guidelines for the following issues:

Team Training Needs Analysis System

Needs Analysis Survey
Multiphase Analysis of Performance

Team Performance Measurement System

Teamwork Skills Measurement
Training Evaluation Measures
Diagnostic Mechanisms

Team Training System

Exercise Development
Team Training Strategies
Crosstraining
Stress Exposure Training
Team Leader Training

Computer Technology
Embedded Training
Computer-Assisted Instruction
Networked Systems for Team Training

Instructor/Observer Training System

Training Delivery
Pre-Training Capabilities Diagnosis
Task-Related and Team-Related Guided Feedback

MILESTONES

Team Training Needs Analysis System

TECHNICAL AREA	BY 1995	BY 2000
Needs Analysis Survey	Develop/Refine Guidelines for Implementing	Implement in new or fielded systems
Multiphase Analysis of Performance	Develop/Refine Guidelines for Implementing	Implement in new or fielded systems

MILESTONES (CONTINUED)

Team Performance Measurement System

TECHNICAL AREA	BY 1995	BY 2000
Teamwork Skills Measurement	Develop/Validate prototype human performance modeling measures Develop/Validate prototype critical incidents/scale development	Provide guidelines for human performance modeling development Provide guidelines for performance measurement development
Training Evaluation Measures	Develop/Validate prototype training evaluation measures	Provide guidelines for training evaluation measures
Diagnostic Mechanisms	Develop/Validate prototype measures	Provide guidelines for diagnostic mechanism development

Team Training System

TECHNICAL AREA	BY 1995	BY 2000
Exercise Development	Develop/Refine principles of exercise development	Provide guidelines for exercise development
Team Training Strategies	Develop/Refine principles of crosstraining Develop/Refine principles of stress exposure training development Identify behavioral requirements of effective team leadership	Provide guidelines for crosstraining development Provide guidelines for stress exposure training development Provide guidelines for team leader training
Computer Technology	Establish requirements for embedded team training Establish requirements for computer-assisted instruction Establish requirements for networked team training systems	Provide specifications for embedded team training Provide specifications for computer-assisted instruction Provide specifications for networked team training systems

MILESTONES (CONTINUED)

Instructor/Observer Training System

TECHNICAL AREA	BY 1995	BY 2000
Training Delivery	Establish requirements of training delivery	Develop guidelines for training delivery
Pre-Training Capabilities Diagnosis	Establish requirements of pre-training assessment	Develop guidelines for pre-training assessment
Task-Related/Team-Related Guided Feedback	Develop/Refine feedback and debrief mechanisms	Develop guidelines for feedback and debrief mechanisms

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THREAT MODELING AND COMMON DATA BASE

DESCRIPTION OF TECHNOLOGY

Simulation of the tactical environment is essential for meaningful mission training in all types of devices used for training in tactical decision making and weapons systems operations. Training must be provided for missions involving electronic warfare, threat recognition, threat interception and/or avoidance, terrain masking, countermeasures use, and offensive/defensive weapons deployment. Elements of the tactical environment include operational platforms (air, surface, ground, etc), emitters, IFF responses, active and passive countermeasures, weapon performance and lethality, and the effects of ambient conditions on detectability and performance.

Threat models have typically been developed on a custom basis to suit individual applications. This has resulted in a proliferation of models with widely varying capabilities in terms of fidelity, computational requirements, growth potential, and user/operator interface. Recent advances in computational power, simulator interoperability, and visual image generation have raised user expectations for threat simulation and emphasized the need for supplying common threat models, especially for networked training devices. Current efforts to bring some order to the existing chaotic state of threat modeling have revealed the following key issues:

Data Sources. The data required to describe threat weapon system performance and threat operator behavior are gathered by multiple intelligence agencies for a multitude of purposes not related to real-time simulation applications. The developers of threat (and "friendly") models must gain access to these data sources and then overcome data shortcomings for real-time model development.

Common Models. The diversity of threat models can be improved to reduce duplication of effort by focusing on user requirements and associating them with model complexity and fidelity. Tactical environment simulations developed for battle group commander training lack the granularity necessary to support individual operator training. An orderly process for associating threat model capabilities with user requirements is needed. Performance metrics must be developed to characterize significant implementation issues such as computation power and model validation. A system for establishing and maintaining configuration control is needed for model credibility, commonality, and reusability.

Human Operator Models. Computer programs are needed to control the large number of weapon platforms in a tactical training scenario. This control must be formulated on several levels: individual platform dynamics and fire control, battery/site operation, and overall order of battle. In many applications, the user desires that these models have selectable skill levels.

Simulation Architecture. The tactical environment simulation must be hosted in an open architecture manner to ensure maximum growth potential and flexibility. Architecture design must not preclude the use of emerging computer capabilities and must accommodate a wide variety of model types and software data structures.

User Interface. The set-up, control, and monitoring of tactical scenarios must be optimized so that individual instructors can manage these complex problem worlds and realize effective training. Model data structures must be accessible to allow modifications by users for "what if" exercises, automatic scenario generation is needed to simplify instructor tasks, and meaningful displays and parameters must be defined to assist in battle management and debrief roles.

Interoperability/Correlation. Tactical environment simulations must be capable of supporting a network of weapon system trainers, including dissimilar devices. Threat models must exhibit common, compatible characteristics to all network nodes. Threat databases must correlate with all other databases (visual, radar, IR, etc.).

MILESTONES

TECHNICAL AREA	BY 1995	BY 2000
Data Sources	Develop process to coordinate access to data sources for weapon system performance and operator behavior	Intelligence agencies fully integrated into threat modeling process
Common Models	Develop guidelines and standards for user needs, performance metrics, and configuration control	Establish an information clearing house for reusable models
Human Operator Models	Develop guidelines for model structure and selectable skill levels	Develop standard models for several classes of human model applications
User Interface	Develop guidelines for automated scenario generation, model access, and battle management monitor and review	
Interoperability/ Correlation	Demonstrate network of dissimilar weapon system trainers with common threat environment	Develop guidelines for network operation Develop fully correlated data sets

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AUTOMATIC SCENARIO GENERATION AND SCENARIO CONTROL

DESCRIPTION OF TECHNOLOGY

New concepts are required for effective utilization of tactical training systems of the 90s. A ten-fold increase in the total number of tracks currently simulated for tactical training systems is a requirement. However, no corresponding increase is anticipated in the number of training system instructors to generate or control training system scenarios using this increased number of tracks.

Scenario generation and scenario control are two separate and distinct instructor functions. Scenario generation is normally an off-line nonreal-time function of initializing forces according to location/mission and identifying intended movement of forces according to a timeline. This function is required even in those systems which are designed primarily as "non-canned" or "freeplay" training systems. In the past, scenario generation or the development of one tactical scenario could take as long as six weeks for a shore based tactical training facility and as long as nine months for an embedded tactical training system.

From a fleet perspective, the issues that need to be addressed for scenario generation are: (1) ensure the economy of time and effort for scenario setup; and (2) make the user-machine interface as easy as possible to use.

The training system instructor scenario control function consists of both monitoring tracks within a scenario while it is running real-time with students/team and also providing performance measurement and feedback of performance in a timely manner.

Specific fleet requirements for 1990s scenario control are: (1) reduce the instructor workload, e.g., assist the instructor with "modifying track parameters" such as course and speed during a coordinated attack for multiple tracks in a multi-ship training evolution, (2) allow instructor to monitor more information, and (3) provide real-time performance measurement and feedback of student performance.

Fleet readiness and mission effectiveness will be enhanced with the application of new technologies to automate the instructor training system functions of scenario generation and scenario control. In addition to upgrading existing tactical training systems, the automation of these functions will be critical to the successful implementation of new acquisitions such as the Tactical Combat Training System (TCTS).

The new technologies will provide rapid development and operation of training system exercises that are representative of operational events. The time required to create a typical scenario will be reduced from 6 weeks to 1 week. The amount of information required to specify a scenario will be reduced by over 90%. During control of scenarios, instructors will be provided multiple windows to increase the amount of information monitored, automatic warfare advisors to increase instructor response to rapidly changing tactical situations, and automatic performance measurement and feedback to provide timely evaluations of exercise successes.

Major technological advances in expert system design, hardware, and software are now available to automate training systems' scenario generation and scenario control processes. These technological advances include a combination of one or more of the following: Expert Systems/Neural Nets; Data Bases; and User Interface technologies.

EXPERT SYSTEMS/NEURAL NETS

Automatic Initial Force Stationing. Automatic initial force stationing for blue, orange, and white forces is technically feasible and has been demonstrated. However, the most efficient design and grouping of rules need to be assessed and documented.

Track and Force Modeling. Current scenario generation/control capabilities produce scripted scenarios. These scenarios script the actions of forces so that without trainer intervention, the scripted forces follow a time tagged series of events after scenario start. With the emphasis now changing from scripted scenarios to "free play" scenarios, pseudo forces need to be designed as objects that take actions based on their own unique attributes, capabilities, missions, and a set of rules. The rules force the object to react to actions taken by other objects.

At scenario start these objects take actions based on their attributes, capabilities, missions, and a set of rules. The rules force the object to react to actions taken by other objects (including the trainees) within the scenario producing a dynamic, intelligent scenario.

Automatic Instructor Situation Assessment. One of the major functions of an instructor is situation assessment. The amount of information an instructor monitors has increased and will continue to increase in the 90s. Automatic situation assessment tools would reduce the instructor workload while allowing him to monitor more information. The demonstration of an automatic Anti-Air Warfare (AAW) situation assessment tool would be developed.

Automatic Real-Time Performance Measurement and Feedback. An expert system can capture the rules the student is expected to follow in a specific situation. These "built-in" expert system rules can be compared to the student's actual actions in real-time and provide an assessment of student/group performance. A prototype expert system would be built.

DATA BASES

Force Element Characteristics/Maps. The Navy standard data bases are currently provided in a relational format. Expert system shells utilize an object oriented data base format. The most efficient method of transforming this relational data to object oriented data will be determined. Navy standard data bases are large. A subset of the data base may be sufficient for automatic scenario generation and control. Also, the choice of data base to support the display of maps needs to be determined.

USER INTERFACE

Multi-Windowing and Graphics/Friendly User Machine Interface. Multi-windowing and graphics are the major technologies for making the user-machine interface easy to use. Current methods for instructors to interface with training systems during the scenario generation process is primarily based upon "textual" and limited graphics presentations. Recent studies indicate that a "picture" or "icon" approach can improve the user's overall productivity by 75%. The incorporation of icons into the scenario generation/control process can significantly improve ease of use and reduce operation time. The issues of number of windows, types of graphics, and window content would be answered through prototyped systems.

MILESTONES

TECHNICAL AREA	BY 1995	BY 2000
Expert Systems/ Neural Nets	o Implement Automatic Force Stationing for a Battle Group o Provide proof of concept demo for automatic track & force movement modeling for multiple ships o Determine requirements for Automatic Instructor Situation Assessment Aid o Determine requirements for Automatic Real-Time Performance Measurement and Feedback	o Implement Automatic Force Stationing for Battle force o Demo automatic track & force movement for blue/orange Battle Force o Demo Automatic Instructor Situation Assessment Aid o Demo Automatic Real-Time Performance Measurement and Feedback
Data Bases	o Integrate subset of Naval Warfare Tactical Data Base into Automatic Scenario Generator o Integrate standard Navy data bases for maps into Automatic Scenario Generator	o Integrate entire NWTDB into ASG o Re-evaluate current standard Navy data bases for maps and determine if new features can be used
User Interface	o Demonstrate system that permits user to modify an Automatic Scenario Generator knowledge base o Demonstrate use of multi-windowing, graphics, menus, to enhance user productivity	o Complete system that permits user to modify ASG knowledge base o Complete implementation of user interface

AI/EXPERT SYSTEM

DESCRIPTION OF TECHNOLOGY

Artificial intelligence has grown rapidly in the past few years to encompass a wide spectrum of technologies. The two most promising for simulation and training systems technology appear to be neural networks and expert systems. Both seek to transfer knowledge into computers. Expert systems are used when the knowledge can be translated into rules. Neural networks are used when it is difficult to translate the knowledge into rules, but it is easy to develop examples of "good" and "bad" performance. Generally, it is so expensive to develop sufficient examples, that neural network technology is not considered ready for routine application in training systems.

Expert systems technology does appear to hold near-term promise for training systems applications. Its impact can be described as a natural progression of simulation technology, itself. In one sense, many training systems use a range of techniques to create the illusion of reality. For example, mathematical equations of motion and trajectory generate data that drives moving targets and platforms such as aircraft and ships. The FORTRAN language was a great improvement over assembly language, because it was easier to validate the mathematical equations. Models are used to present the targets and platforms in a sufficiently realistic form that the student can imagine an interaction is taking place. Expert systems technology has the potential to carry knowledge into the training system computer that traditionally was carried by the instructor or by the operator acting as an adversary to the student. That is, both knowledge of how and what to teach as well as knowledge of human interactions can be represented in the training system using expert systems technology. Of course, clever programmers have had the capability to code such knowledge in FORTRAN or other popular languages. The major difference with expert systems is that these shells allow coding of knowledge in a higher order language, more like experts think. Therefore, it is easier for experts to validate the code. That was the same benefit FORTRAN gave over assembly language for programming mathematical equations. Thus, expert systems provides the next step in the evolution of training systems. Three applications for expert systems that have had recent attention are intelligent agents, scenario control, and instructional delivery.

An intelligent agent in a training system can be an interactive platform that is either hostile or friendly. The goal is to derive from the instructors sufficient knowledge of how the enemy and allied forces act that agents can be created in software to mimic their behavior. Of course, the skill must also vary because if the adversaries are too good and nearly always beat the student, learning may not take place efficiently. Therefore, the forces must adjust to the fact that they are operating in a learning environment. Elements include tactics and rules of engagement.

Scenario control in a training system can serve to guide both the initial force laydown in a military training operation as well as playout of the exercise. Most complex command and control training systems require many days and sometimes many months of instructor time to set up and test any one scenario. Unfortunately, repeated training on the same scenario may result in students learning the quirks of the particular scenario instead of the concepts of engagement intended by the exercise. Therefore, an expert system which would develop a scenario from a mission objective would also give practice for multiple situations. Elements include exercise objectives, strategy, exercise preview and playout, short-term interventions, and review/replay.

Instructional delivery in a training system can provide a tutor that tailors the course to the individual student. This will ensure that each student gains the maximum knowledge in the minimum time. It might also overcome the dilemma of having the best pilot, say, being the worst instructor. That is, an expert may be quite good at doing the job, but terrible at teaching someone else how to do it. By capturing pedagogical knowledge, a training system can teach using the best educational practices. Of course, it must have something to teach. Thus, instructional delivery requires domain knowledge. The elements of pedagogical knowledge include assessment (pre, in progress, post), presentation (demonstrations, guided practice, free play), and remediation (revised presentation, determination of asymptotic performance threshold). The elements of domain knowledge include the material's quality, robustness, reliability, validity, and comprehensiveness. The material is concepts, facts, examples, analogies, and performance criteria.

Certain tools are needed to implement expert systems technology in training systems. Just as FORTRAN required flow charts, compilers, assemblers, and linking libraries, expert system technology requires tools and techniques. For training system applications, these techniques and tools include knowledge acquisition, knowledge representation, inference, test case performance, documentation, and reusability.

Knowledge acquisition is akin to systems analysis in traditional training systems. Many attempts have been made at developing automated knowledge acquisition tools. Many books are written about it. A discipline has developed called Knowledge Engineering. The technique is still in its infancy. The dilemma is that the knowledge of the expert must be extracted and translated into rules. The expert often does not articulate the knowledge in a way that the programmer can translate into rules easily. Likewise, the programmer does not know enough about the domain to ask the right questions the first time. Thus, the process is lengthy and iterative in nature for complex tasks. There are tools for acquiring knowledge in specific domains for specific tasks. However, the task of developing a general knowledge acquisition system is not yet complete. The elements of knowledge acquisition include requirements analysis, cost of allocation of the expert's time, "lost" and "unused" knowledge inventory, and revisions to the knowledge base. The knowledge that must be acquired is addressed in the discussion above.

The current techniques for training system acquisition include task and system analysis. The task and system analysis of a training system has standard reporting formats. Likewise, knowledge acquisition from a domain expert must be documented. For training systems, representation of knowledge is critical to eventual acceptance testing. Automated acquisition systems have used various techniques to represent what is acquired. In general, two forms of knowledge must be represented, procedural knowledge and declarative knowledge. Declarative knowledge is most often represented as rules and procedural knowledge as processes. Elements of representation, as applied to training systems, include the performance specification, debugging, validation and verification, rule/process revision, and maintainability.

Expert systems perform their work through a process of inference. As events occur in a training system, the expert system must check through its knowledge base of rules and determine whether to take some action. Typical inference mechanisms include inductive reasoning (forward chaining), deductive reasoning (backward chaining), and probabilistic reasoning. Essentially, expert systems operate on elaborate search strategies, determining which "IF-THEN" rules apply at any given event. The search can be for a set of rules that match the conditions, the best rule that matches, or the first rule that matches.

Acceptance testing of a training device validates that it performs as intended. Generally, test cases are used for this purpose. For training systems that incorporate expert systems technology, the test cases must assure that the system "thinks" like the expert. All important variations must be tested to assure the system will perform during training. One approach to development of test cases is to follow psychological guidelines on human sampling of skills. Thus, analysis of variance techniques can be employed to test the system the way one might test a human subject. This approach appears more and more economical as the knowledge base increases in size.

Most training systems are eventually modified. Documentation of rules of the expert system is required for the same purpose as documentation of the rest of the training system, to assist in modification and maintenance. For example, the domain knowledge may change as additional intelligence is collected. The adversary platforms may change as the opposition acquires advanced technology. Our own maneuvers may change as operational forces learn lessons in future engagements. Basis of documentation for expert systems is the knowledge representation system. It must map into rules. In addition, the documentation must describe the interrelationship of the rules, so that the impact of modification can be predicted.

Reusability of software is gaining popularity. Certainly, expert systems can incorporate this concept in its knowledge bases. The "IF-THEN" English-like structure of rules should make reusability easier. However, there are currently no standards for the use of expert systems in training systems. As applications grow, the risk of unique knowledge bases also grows. The elements of reusability include the rules, the representation language and the implementation language.

Explanation is a human process that is often used to validate that communication has been understood. Most expert systems use an explanation capability as a debugging tool. The system can explain its rule sequence to an expert when the expert questions the conclusion drawn by the system. The system can also explain its rule sequence to a student as a way to instill a particular logic sequence in the student's performance habits.

CRITICAL TECHNOLOGY CHALLENGES IN EXPERT SYSTEMS

-- Intelligent agents
-- Scenario Control
-- Instructional
  Pedagogical
  Domain Knowledge
-- Knowledge Acquisition
-- Knowledge Representation
-- Inference
-- Test Case Performance
-- Documentation/Maintainability
-- Reusability
-- Explanation

MILESTONES

TECHNICAL AREA	BY 1995	BY 2000
Intelligent Agents	Establish data base of various platform tactics, both friendly and adversary	Establish repository for high quality adversary and friendly platforms
Scenario Control	Develop automatic scenario generation workstation capabilities to reduce time and increase flexibility Develop automatic scenario control software concepts for friendly and/or opposing forces to use intelligent agents and reduce manning	
Instructional Pedagogical Domain Knowledge	Develop expert teacher for reuse in various intelligent training systems Develop structure for collection of domain knowledge for training systems	Develop domain independent expert teacher for curriculum development and control Develop standards for archiving domain knowledge of the "best" operators
Knowledge Acquisition	Develop automated knowledge acquisition system for pedagogical and domain knowledge	Develop domain independent knowledge acquisition system for theater wargaming
Knowledge Representation	Develop standards for declarative and procedural knowledge representation	
Inference	Develop standards for reasoning in expert systems for training	Order of magnitude speed increase in search strategies
Test Case Performance	Develop methods of test case generation for pedagogical expert systems	Develop methods of test case generation for domain expert systems
Documentation	Develop techniques for documentation of rules and their interrelationship	Develop automatic debugging tools for knowledge base modification
Reusability	Develop techniques for reuse of platforms and tactical rules	Develop standards for expert systems shells
Explanation	Develop techniques for pedagogical explanation of domain knowledge	

PAYOFF/VALUE ADDED

The payoff/value added with expert systems technology accrues to the evolution of software into increasingly English-like code. That is, expert system technology can provide higher order knowledge beyond that of mathematical equations to be used in training systems. This opens the door to use of pedagogical and domain knowledge directly instead of requiring software analysts and engineers to translate knowledge into lower order computer languages. This speeds the process of development, debugging and modification of training systems by giving development tools directly to the subject matter experts. Further benefits accrue when the training systems become richer in knowledge. When training systems have resident expert systems, it is possible to reduced manning of devices, and that lowers the cost of training. At the same time the system continues the high level of knowledge being imparted to students because of the resident expert systems. Finally, expert systems can tailor training to the individual student, thereby promoting maximum learning in minimum time.

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VISUAL/SENSOR SIMULATION

DESCRIPTION OF TECHNOLOGY

Visual/Sensor simulation is a technology area which encompasses a number of enabling technologies. The enabling technologies are: simulation requirements analysis, optics, computer image generators/graphics, light valves, CRT's, laser displays, liquid crystal displays, digital data bases, photo data bases visual perception and variations or combinations of these.

The Visual/Sensor simulation areas of application range from aircraft flight simulators with fifty foot diameter dome displays to compact helmet mounted displays or night vision goggles for the visual areas. In the sensor areas, there are simulations of forward looking infrared (FLIR) Low Light Level (LLL) TV and advanced radars such as synthetic aperture radar (SAR) and inverse SAR (ISAR). Visual/Sensor simulation is also used in all types of weapon fire simulation such as artillery, tank and antitank weapons and infantry weapons.

Many new developments in the enabling technologies are reducing cost, increasing performance and decreasing size of the visual/sensor simulation systems. Computer cost reductions and capability advances lead the way in computer image generation technology. New developments in data bases include photographic augmentation of CIG systems and rapidly reconfigurable data bases which are lowering costs and increasing realism of visual simulation systems. New developments in light valves and high brightness CRT's will increase brightness, resolution, and reliability of projection systems.

Developments in high definition TV (HDTV) should lower cost and improve performance of visual/sensor simulation systems as these new components become available from mass production efforts. The new components will be higher resolution TV monitors and cameras, low cost broad bandwidth components, and network capabilities which will increase the use of visual/sensor simulation in networked systems. One technology push that will increase performance and lower cost of visual/sensor technology is the development of Virtual Reality technology. This technology will put in the hands of the public the ability to experience or live-out their virtual worlds through high quality visual simulation combined with other sense simulations.

MILESTONES

TECHNOLOGY AREA	BY 1995	BY 2000
High Quality Low Cost CIG	1990 Performance at 1/10 Cost	PC Size and Cost with Performance Limited Only by User's Vision
High Quality Light Weight Optics for HMD	Etched Plastic Optics Wide Angle Well Corrected	Low Cost Helmet Mounted Displays (HMD's) Available to Public
Advanced CRT's and Light Valves	2000 Lumen CRT's Low Maintenance Light Valves	2000 Line Resolution 4000 Lumen CRT's Low Cost Light Valves
Automated Photographic Data Base Generation	Texture Recognition and Semi-Automated Feature Extraction from Photos	Neural Networks for Image Analysis and Data Base Generation
HDTV	Components Designed and Ready for Marketing	In General Use by Public and in General Use in Networking for Training

APPENDIX D

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